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ABSTRACT

Data presented in this report indicate that solar space and water heating are possible in the Pacific Northwest. The first section of the report contains solar records from several stations in the region illustrating space heating needs that could be met, on an average daily basis, by solar energy. The data are summarized, and some preliminary planning hints are offered including analyzing a site for solar collector suitability, and a procedure for sizing a collector and storage tank. The second section discusses two of the earliest solar collector houses in the area and compares them with three well-known solar houses elsewhere. A selected bibliography on solar energy in architecture is included. The concluding section contains photographs and descriptions of local design solutions that exclude summer sun but welcome winter light, including the effects of trees and vines. Climatological charts, based on eight years of data from the weather bureau at the Eugene airport, are included for the purpose of exploring low-energy building design in general. (MLF)

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ED131539

SOLAR ENERGY FOR PACIFIC NORTHWEST BUILDINGS

John S. Reynolds, Associate Professor of Architecture

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NATIONAL INSTITUTE OF EDUCATION

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INTRODUCTION

Our heavily populated portion of the Pacific Northwest beyond the Cascades has traditionally been considered unpromising for solar energy utilization. This is primarily due to our persistent heavy winter cloud cover and abundant cheap hydro-power. Even the exceptionally clear summers have not attracted much solar experimentation, as the usually cool and breezy weather makes mechanical air conditioning for residences unnecessary. Indeed, perhaps the clearest way to make a case for solar energy research in the maritime Pacific Northwest is to say that demonstrated feasibility here would make feasibility anywhere else, by comparison, much more likely.

There are other reasons beside "if we can do it, anyone can" for researching solar energy in our region:

1. The few coldest days that occur in the Pacific Northwest winter are usually clear ones; solar energy thus increases suddenly as does the need for space heating. This could make solar energy attractive as a utility peak-shaving aid.

2. As elsewhere, Northwest energy costs are increasing rapidly. Bonneville Power Administration increased wholesale power rates for the first time in 1974 - by about 27%.

3. Again, as elsewhere, lighting levels in buildings have increased to the point that summer - and even fall and spring - cooling of commercial structures is desired. Three factors make solar energy particularly appropriate for this cooling:

   A. The dependability of solar energy for hot days when its cooling work is needed. Hot and dry clear days, rather than overcast muggy ones, are the typical Northwest pattern.

   B. The average clearest skies of the year are those of our summer nights. Radiant night sky cooling is thus a possibility, with potential year-round usefulness for certain types of solar collector/radiator combinations.

   C. The lowest flows of Northwest rivers, hence the lowest production of hydropower, coincide with our warmest weather. A growing summer peak in electrical demands, as has happened elsewhere, is a partcular threat to Northwest power systems.

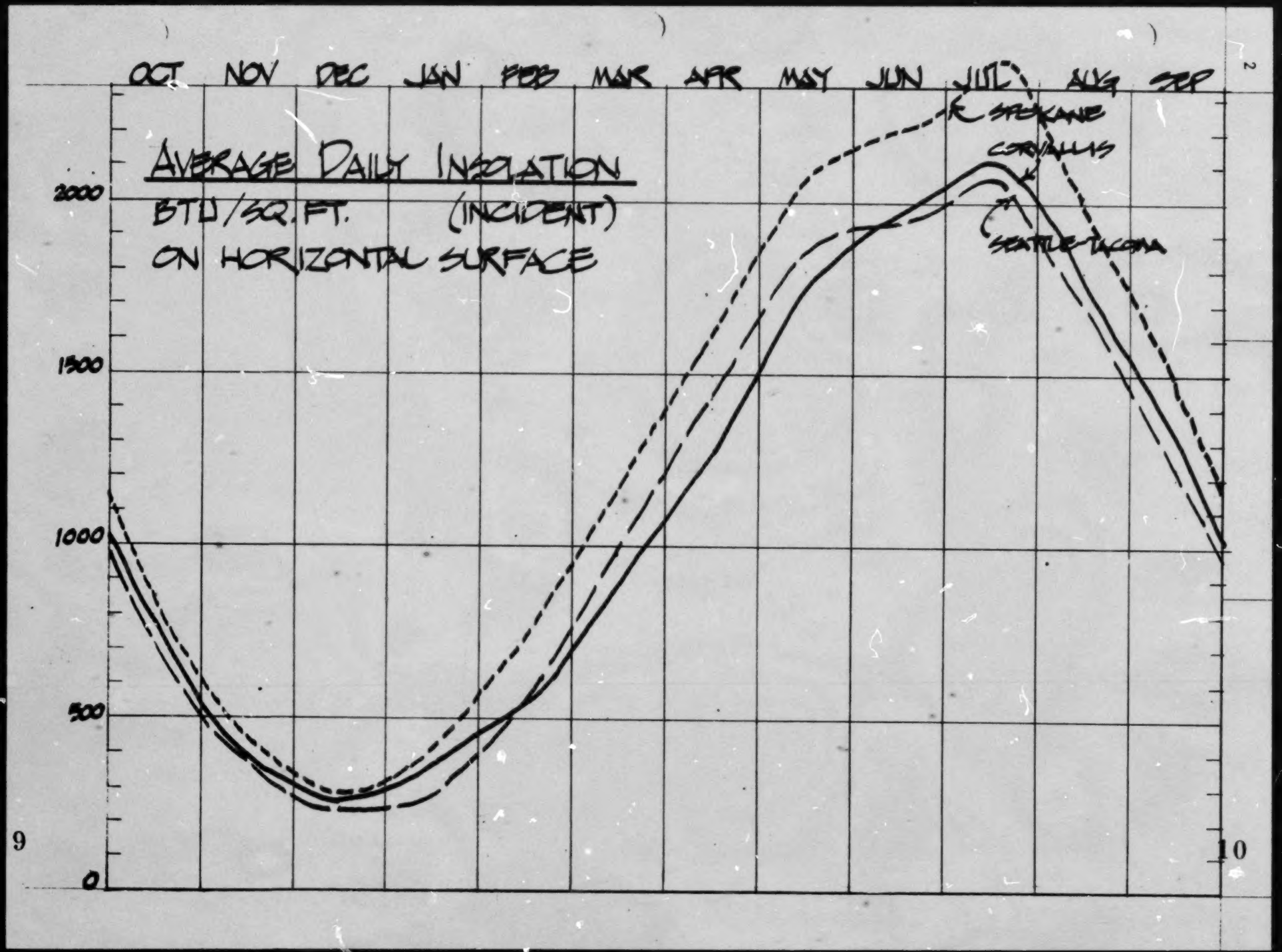
I have also personally experienced a climate of public acceptance of essentially renewable energy sources in the Northwest, beginning with hydro years ago and turning toward geothermal, waste burning, wind and solar energy. This attitude contrasts with my sense of growing public reluctance for non-renewable sources such as coal, oil, gas and uranium. Solar research could thrive in such an environment.

PART ONE: SOLAR DATA

The lack of adequate data on solar radiation in the Pacific Northwest is keenly apparent in this section. There is not an adequately widespread network of solar radiation measuring stations; some of these few stations measure only spring through fall for exclusively agricultural purposes. Several stations no longer include solar radiation (insolation) on the monthly Climatological data sheets; one must write to Asheville, N.C. to obtain the data. Gaps in day to day readings occur when recording equipment malfunctions are not immediately noticed and corrected.

Solar data is recorded only on horizontal surfaces, and distinctions are not made between diffuse-only and direct-plus-diffuse radiation. This hampers decisions as to proper conversion factors from horizontal to tilted surfaces, and obscures both the "optimum tilt" and "optimum bearing" for solar collectors in this region.

Adequate solar records could change the preliminary conclusions of this part fairly substantially. When the suggestions for further research (last page) have been followed through, further revised versions of this report are sure to follow.


OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP
AVERAGE DAILY INSOLATION
BTU/SQ. FT. (INCIDENT)
ON HORIZONTAL SURFACE
2000
1500
1000
500
0
SPOKANE
CORVALLIS
SEATTLE-TACOMA

AVERAGE DAILY INSOLATION

Measured on a horizontal surface. One daily average for each month is plotted.

Comment: Willamette Valley (Corvallis) average insolation appears to slightly exceed Puget Sound area averages from October through January, and falls below those averages from March through May. Insolation is consistently higher in Spokane, though only slightly higher from October through January.

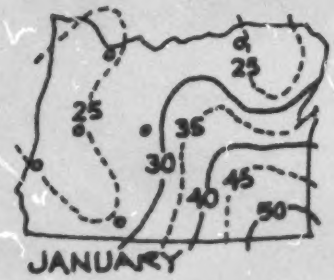
Sources: Corvallis (Hyslop Experimental Farm) data (8 year average 1961-63, 1970-74): Earl Bates, NOAA representative at Oregon State University.

Seattle-Tacoma Airport: Climatic Guide for Seattle and Adjacent Puget Sound Area, Table 41 (1950-1960).

Spokane: Local Climatological Data, for 19 year period.

4 % POSS. SUN

BTU/SQ.F./DAY



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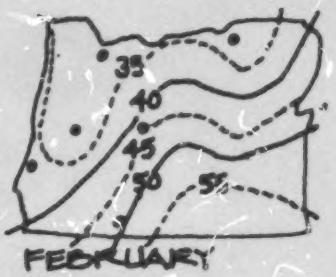

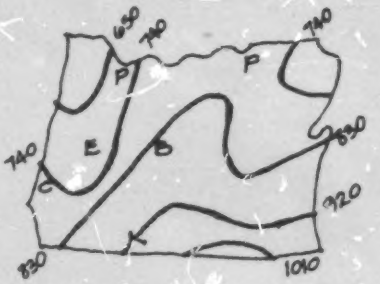

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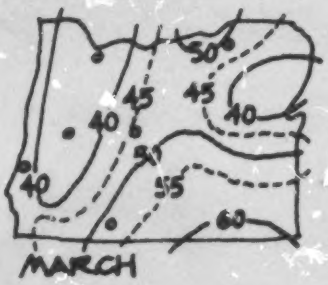

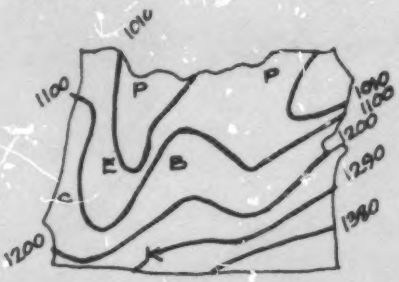

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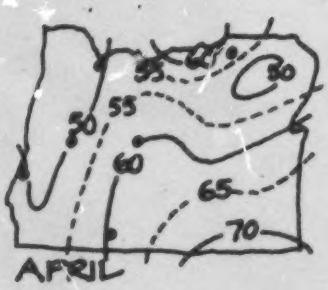

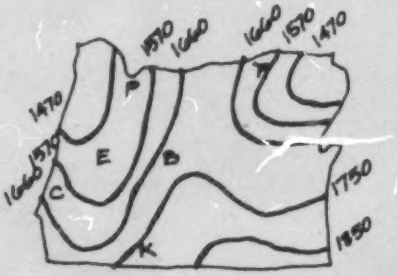

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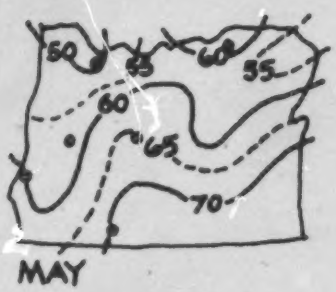

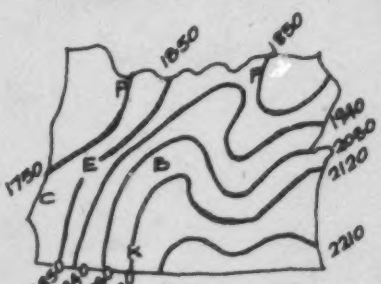

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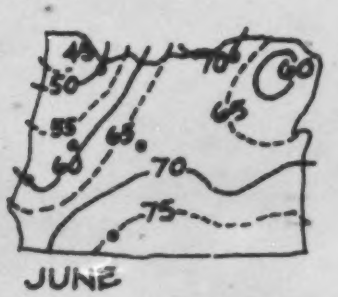
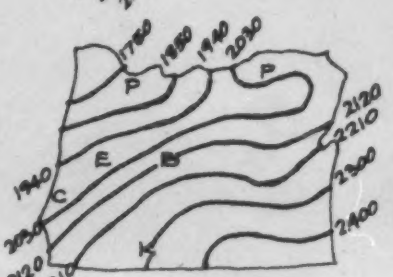




JUNE

DEGREE-DAYS
(AVERAGE ANNUAL)

B · BEND
C · COOS BAY
E · EUGENE
K · KLAMATH FALLS
P · PENDLETON, PORTLAND

INFORMATION SOURCE:

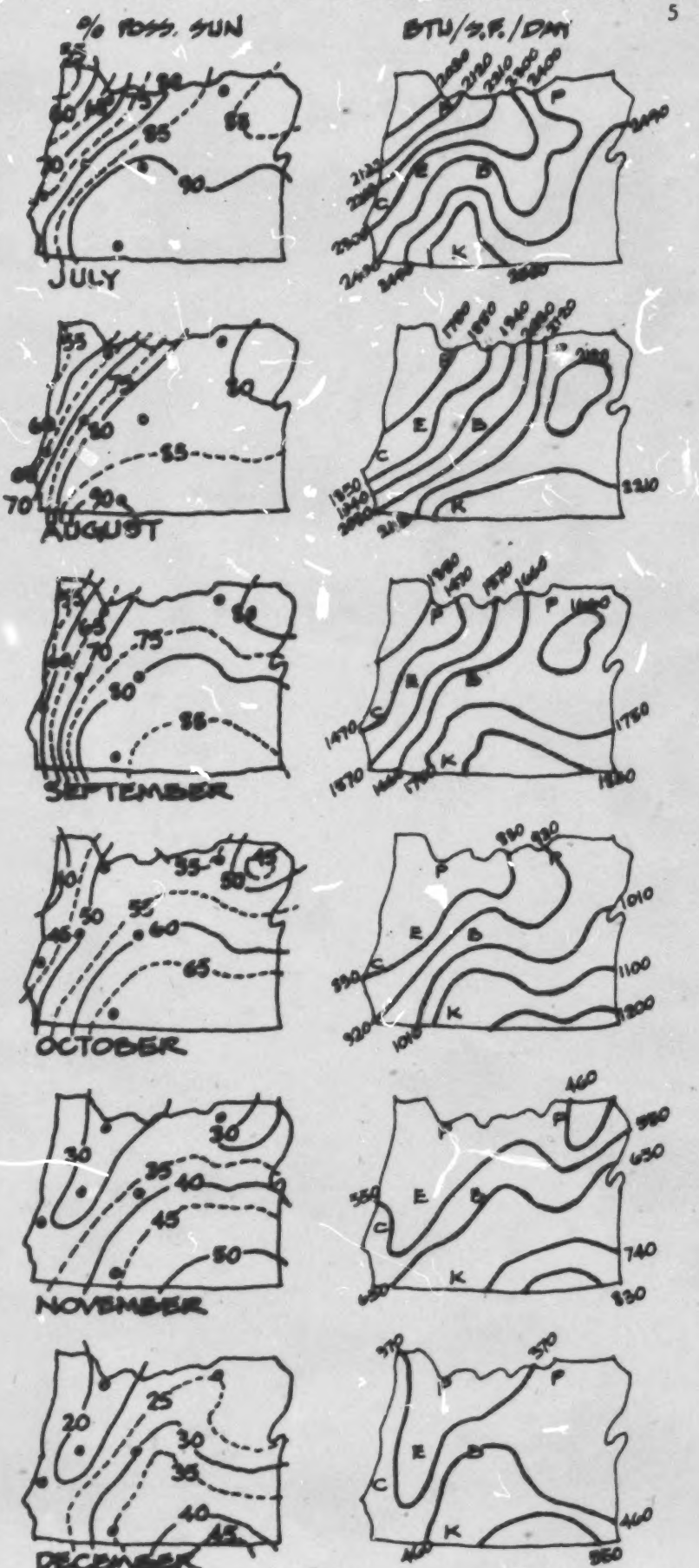
OREGON

MONTHLY AVERAGE COMPARISONS:

PERCENT POSSIBLE SUNSHINE,

INSOLATION ON HORIZONTAL SURFACE BTU/SQ.FT./DAY

8 YEAR AVERAGE



WEEKLY WEATHER & CROP BULLETIN NAT'L SUMMARY, VOL XLVI #25 1959, P.6-8

APPROACHES TO SOLAR HEATING

Utilization of the sun's energy as heat can range from simply providing a large south facing window admitting winter sun to a room, through various approaches to admitting and storing this heat within a room, to more remote collectors with storage tanks. We often call the more simple and direct approaches "passive" systems while the collector-plus-storage systems are called "active" ones. Yet, the degree to which any of these systems is "natural" (passive), "hand-operated", or "mechanized" (active) can vary widely.

Some basic data for the most simple approach, that of simply admitting winter sun directly through an unshaded south window, is shown on the opposite page. In Eugene, the results vary from the unproductive (season net loss) combination of single glass and a 70° internal temperature, to the season net gains obtained from double glass and an internal temperature of 65°. It should be emphasized that these figures do not assume drawn drapes or other semi-insulating devices over the glass at night; clearly, by greatly decreasing the daily heat loss, corresponding increases in net gain result.

The qualities of solar heat admitted on a sunny winter afternoon can quickly overheat a space which does not provide for heatstorage (as in masonry walls, concrete slabs, barrels of water, etc.); the integration of such "thermal mass" in south-window spaces is one of the many opportunities for solar architectural designing.

In buildings without benefit of unshaded south glass (or where direct winter sun in spaces is considered undesirable), the collector-plus-storage systems are used, with the collector typically on the roof (although it can be placed in any location which receives winter sun). The integration of such large (usually flat-plate) collectors with the buildings they serve is another opportunity for solar architectural designing, as is the placement and construction of the storage tank or bin.

INSOLATION vs. HEAT LOSS: SOUTH FACING GLASS in EUGENE

Single Glass U = 1.13
Double Glass U = .69

Actual Insolation: Baker, "Insolation on Tilted Surfaces."
Transmissivity thru single glass: .85
Transmissivity thru double glass: .77

MONTH	AVERAGE EXTERIOR TEMPERATURE (1934-1973)	% of Yearly Heating Degree Days Base 65°	Daily Heat Loss: Btu/sf glass Interior Temp: @70°	@68°	@ 65°	Daily Heat Gain Btu/sf glass South Facing	Daily Net Gain (Loss) Btu/sf glass Interior Temp: 70°	68°	65°
JAN.	39.2°	16.6%	ΔT=30.8	28.8	25.8				
single glass			835	780	699	540	(295)	(240)	(159)
double glass			510	477	427	457	(53)	(20)	30
FEB.	43.3	12.8%	ΔT=26.7	24.7	21.7				
single glass			724	670	588	561	(163)	(109)	(27)
double glass			442	409	359	475	33	66	116
MAR.	45.6	12.3%	ΔT= 24.4	22.4	19.4				
single glass			661	606	520	689	28	83	169
double glass			403	370	321	582	179	212	261
APR.	49.8	9.7%	ΔT=20.2	18.2	15.2				
single glass			547	493	411	640	93	147	229
double glass			334	301	251	541	207	240	290
OCT.	52.8	7.8%	ΔT=17.2	15.2	12.2				
single glass			466	411	330	830	364	419	500
double glass			284	252	202	702	418	450	500
NOV.	45.4	12.4%	ΔT=24.6	2216	19.6				
single glass			666	612	531	496	(170)	(116)	(35)
double glass			407	374	324	420	13	46	96
DEC.	41.1	15.5%	ΔT=28.9	26.9	23.9				
single glass			783	728	648	328	(455)	(400)	(320)
double glass			478	445	395	277	(210)	(168)	(118)

SEASON (OCT. thru APR.) TOTALS: DAILY NET GAIN (Loss), Btu/SF Glass

Unshaded South Glass:

Interior	@ 70°	68°	65°
Single glass	(86)	(31)	51
Double glass	85	118	168

8 Year Average Daily Radiation in Langleys: Corvallis

Horizontal Surface at National Weather Service - Hyslop Field Laboratory, Corvallis, Oregon (44 38'N)

DATE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	85	112	174	195	378	549	569	495	399	331	144	70
2	78	124	189	314	480	503	673	541	446	312	181	68
3	120	111	163	387	448	480	681	533	428	300	136	87
4	101	97	165	306	420	549	554	420	421	267	129	75
5	87	89	182	330	374	516	556	506	368	289	144	64
6	95	121	205	326	316	453	508	494	380	268	144	90
7	92	168	259	339	419	539	533	515	393	276	111	73
8	85	161	275	288	408	468	512	532	401	281	93	65
9	102	124	199	239	353	453	469	533	406	235	114	72
10	109	135	163	351	457	518	516	578	359	202	118	89
11	77	145	213	359	478	474	575	552	432	168	134	97
12	82	125	214	302	488	601	655	450	397	208	109	74
13	68	142	223	353	539	568	590	471	384	210	108	58
14	87	125	207	339	519	456	623	508	361	261	101	55
15	57	123	249	410	445	481	638	489	350	260	97	46
16	71	125	243	326	535	571	543	446	389	261	112	50
17	104	112	331	320	502	538	600	507	382	210	67	93
18	99	134	288	270	511	620	591	473	310	225	73	43
19	110	137	268	331	535	600	606	446	320	150	138	39
20	129	182	324	272	420	572	549	459	263	132	61	39
21	122	165	249	348	558	560	599	434	271	139	65	66
22	123	168	211	394	408	516	570	469	297	129	63	55
23	98	183	269	339	470	528	595	428	349	147	42	57
24	117	181	241	353	442	473	596	381	357	180	74	67
25	129	208	241	424	484	516	562	484	347	172	80	97
26	116	191	206	334	494	538	566	472	346	164	70	72
27	122	183	242	367	544	499	541	441	403	121	97	82
28	137	126	257	400	576	552	607	469	306	168	111	54
29	114		293	347	514	541	561	470	311	205	114	66
30	93		308	376	532	597	569	332	345	152	77	64
31	113		292		573		514	341		118		78
Monthly Total	3,122	3,997	7,343	10,039	14,620	15,829	17,821	14,669	10,927	6,541	3,107	2.105
Average per day	101	143	237	334	472	528	575	473	364	211	104	68

CALCULATING INSOLATION ON TILTED SURFACES

From the 8-year average total insolation on horizontal surface at Corvallis, it is possible to calculate the approximate average total insolation on tilted south-facing surfaces.

The data on the following pages is taken from results of a computer program developed at the University of Oregon by Steve Baker; a more complete description of procedure and results for other Pacific Northwest locations are available in a separate publication through the Center for Environmental Research: "Insolation on Tilted South-Facing Surfaces in the Pacific Northwest" ($1). These locations include:

Alaska; Annette, Bethel, Fairbanks and Matanuska
Alberta; Edmonton
British Columbia; Nanaimo, Cummerland and Vancouver
Idaho; Boise and Twin Falls
Montana; Glasgow and Great Falls
Oregon; Astoria, Corvallis, Klamath Falls, Medford
Washington; Friday Harbor, Prosser, Pullman, Richland, Seattle and Spokane

The procedure for such calculations is taken from both Liu and Jordan's opening chapter in the ASHRAE publication "Low Temperature Engineering Applications of Solar Energy" (now out-of-print) and Chapter 3 of Duffie and Beckman's "Solar Energy Thermal Processes" (Wiley, 1974).

First, the ratio of actual total insolation on a horizontal surface is found to that available outside the atmosphere at same time and latitude. This ratio then leads to three components of the actual total insolation: direct, diffuse and reflected insolation. These components are then adjusted to correspond to the angle of tilt of south-facing surfaces.

Important increases in winter collection are possible by use of a reflector in front of the collector: see description of Henry Mathew's house at Coos Bay, Oregon. A detailed theoretical analysis of the reflector's contributions is available from Professor David McDaniels, Physics Department, University of Oregon: "Enhanced Solar Energy Collection Using Reflector-Solar Thermal Collector Combinations" ($1.00). An abbreviated form of this articale appeared in Solar Energy magazine; Vol. 17, No. 5; November, 1975 (pp 277-283).

CORVALLIS, OREGON
44° 38'

8-year averages
on horizontal surface
at Hyslop Farm

BTU/SQ. FT./DAY
Insolation on south-facing surfaces
Reflectivity from ground, roof assumed at 20%

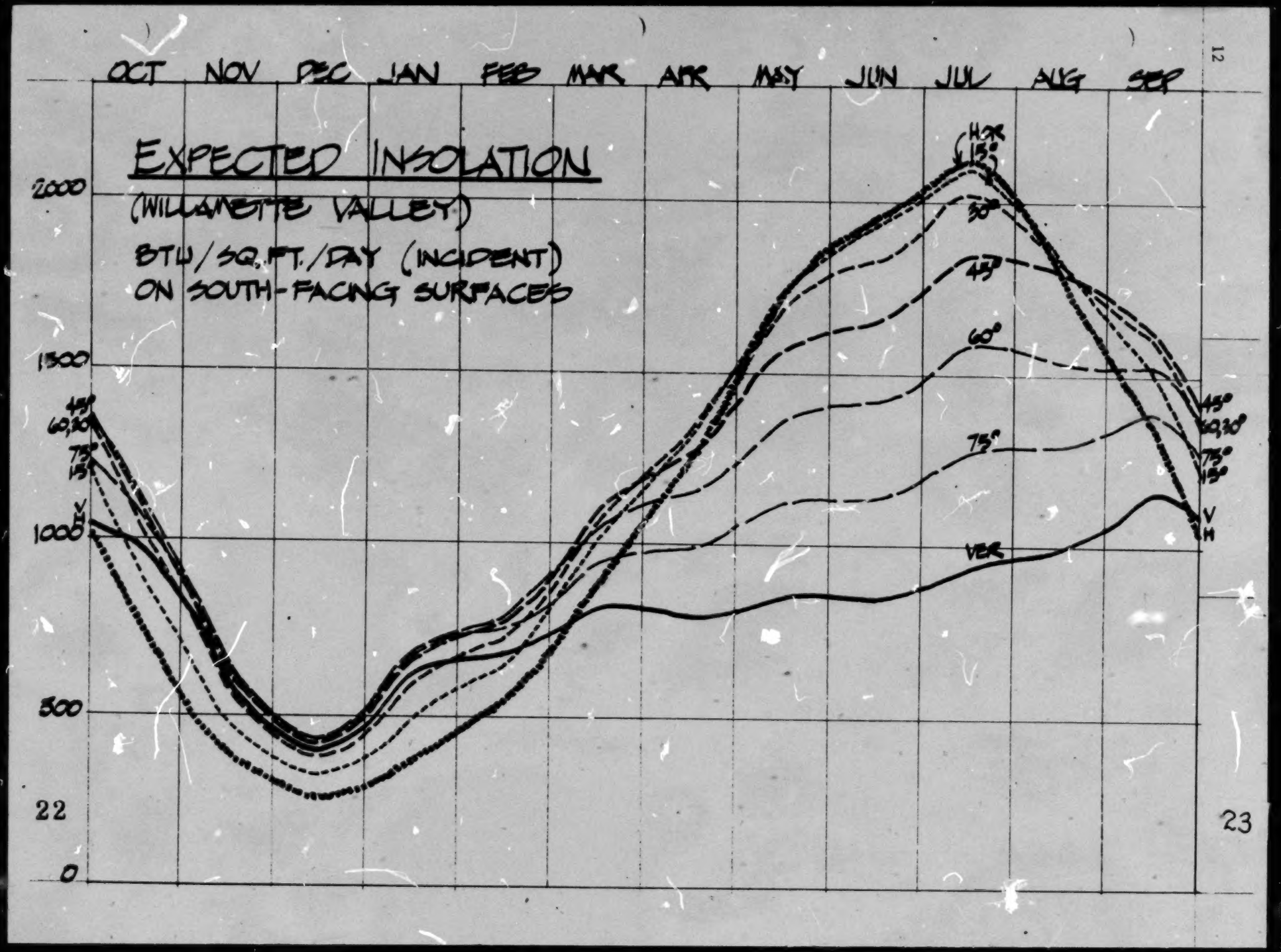
		Horiz.	15°	30°	45°	60°	75°	Vert.
January	Direct	174	298	401	477	521	529	501
	Diffuse	198	195	185	169	149	125	99
KT = 0.34	Reflected	0	1	5	11	19	28	37
	TOTAL	372	494	591	658	688	681	637
February	Direct	242	355	443	501	525	514	467
	Diffuse	285	280	266	244	214	180	143
KT = 0.33	Reflected	0	2	7	15	26	39	53
	TOTAL	527	637	716	760	766	732	662
March	Direct	460	578	657	691	678	618	517
	Diffuse	414	407	386	353	310	260	207
KT = 0.39	Reflected	0	3	12	26	44	65	87
	TOTAL	874	988	1055	1070	1032	944	811
April	Direct	679	750	772	743	665	544	388
	Diffuse	552	543	515	471	414	347	276
KT = 0.41	Reflected	0	4	16	36	62	91	123
	TOTAL	1231	1297	1304	1251	1141	983	787
May	Direct	1078	1097	1053	947	784	576	342
	Diffuse	663	651	618	566	497	417	331
KT = 0.50	Reflected	0	6	23	51	87	129	174
	TOTAL	1740	1754	1695	1564	1368	1123	848
June	Direct	1249	1226	1140	991	788	545	287
	Diffuse	698	686	651	596	524	439	349
KT = 0.52	Reflected	0	7	26	57	97	144	195
	TOTAL	1947	1919	1818	1644	1409	1129	831
July	Direct	1477	1474	1392	1229	996	710	397
	Diffuse	643	632	600	549	482	405	322
KT = 0.58	Reflected	0	7	28	62	106	157	212
	TOTAL	2120	2113	2020	1840	1584	1272	930

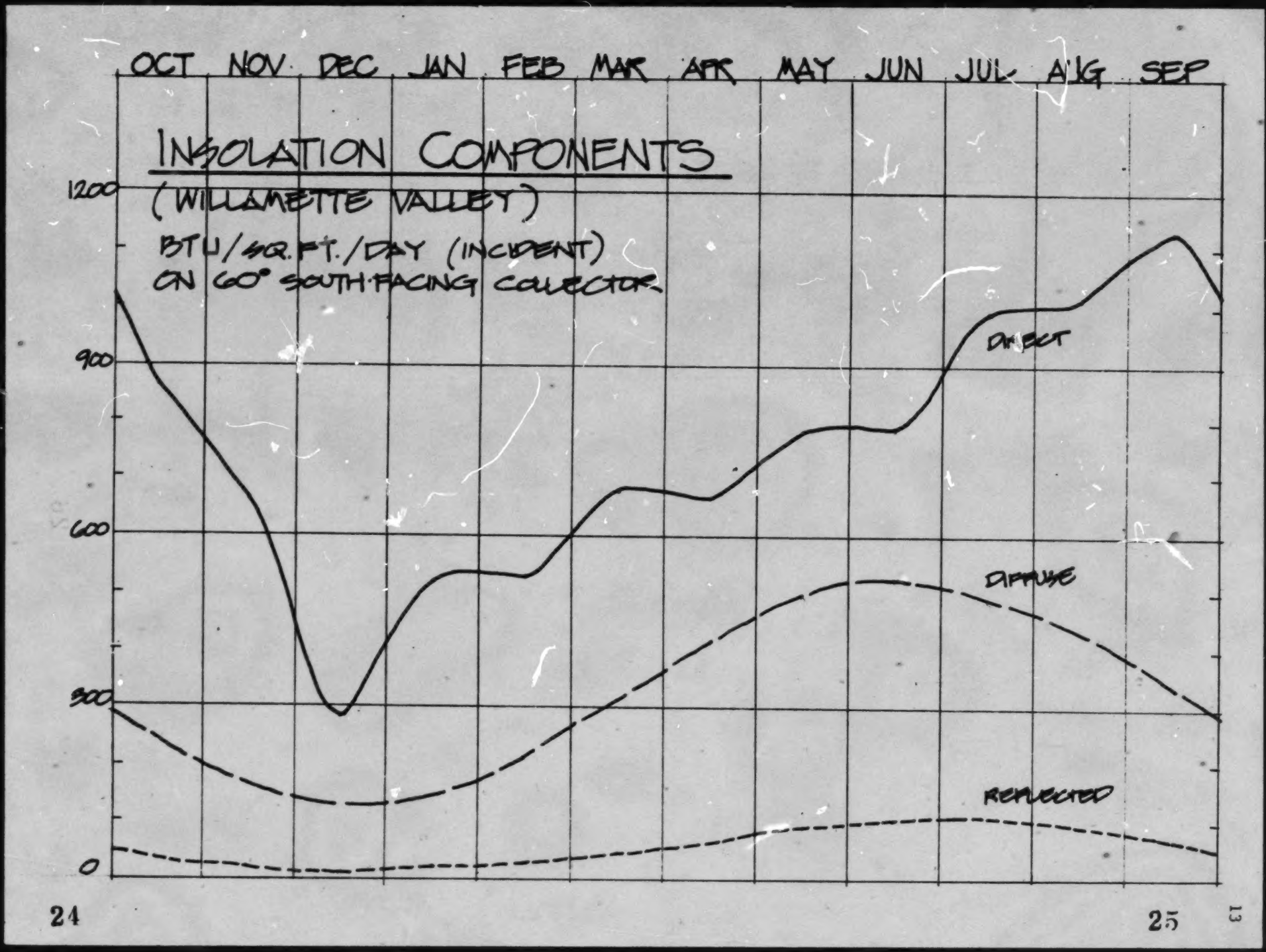
Reflectivity from ground, roof assumed at 20%

		Horiz.	15°	30°	45°	60°	75°	Vert.
August	Direct	1161	1240	1241	1163	1011	794	532
	Diffuse	579	570	541	495	435	365	290
KT = 0.55	Reflected	0	6	23	51	87	129	174
	TOTAL	1740	1815	1805	1709	1532	1288	995
September	Direct	886	1061	1163	1186	1128	994	792
	Diffuse	456	448	425	389	342	287	228
KT = 0.54	Reflected	0	5	18	39	67	99	134
	TOTAL	1342	1513	1606	1614	1537	1380	1154
October	Direct	450	626	759	840	864	829	738
	Diffuse	328	322	306	280	246	206	164
KT = 0.44	Reflected	0	3	10	23	39	58	78
	TOTAL	778	951	1075	1143	1149	1093	980
November	Direct	168	277	367	432	467	471	442
	Diffuse	215	211	201	184	161	135	108
KT = 0.32	Reflected	0	1	5	11	19	28	38
	TOTAL	383	490	573	626	648	634	588
December	Direct	85	154	213	257	284	291	278
	Diffuse	169	166	158	145	127	107	85
KT = 0.27	Reflected	0	1	3	7	13	19	25
	TOTAL	254	322	374	409	423	416	388

AVERAGE DAILY TOTAL INSOLATION FOR SPECIFIC PERIODS (BTU/SF/DAY)
CORVALLIS, OREGON

DEC-JAN	313	408	483	533	556	549	513
NOV-MARCH	482	586	661	704	711	681	617
OCT-APRIL	631	740	813	845	836	784	694
MAY-SEPT	1780	1824	1790	1675	1486	1238	951
ALL YEAR	1113	1194	1222	1193	1108	974	802


OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP
EXPECTED INSOLATION
(WILLAMETTE VALLEY)
BTU/SQ.FT./DAY (INCIDENT)
ON SOUTH-FACING SURFACES
2000
1500
1000
500
0
HOR
15°
30°
45°
60°
75°
VER
45°
60,30°
75°
15°
V
H


OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP
INSOLATION COMPONENTS
(WILLAMETTE VALLEY)
BTU/SQ.FT./DAY (INCIDENT)
ON 60° SOUTH-FACING COLLECTOR.
1200
900
600
300
0
DIRECT
DIFFUSE
REFLECTED

SEATTLE-TACOMA, WASHINGTON
47° 27'

19-year averages on horizontal surface

BTU/SQ. FT./DAY
Insolation on south-facing surfaces
Reflectivity from ground, roof assumed at 20%

		Horiz.	15°	30°	45°	60°	75°	Vert.
January	Direct	112	204	282	341	377	387	370
	Diffuse	169	166	157	144	127	106	84
KT = 0.30	Reflected	0	1	4	8	14	21	28
	TOTAL	280	370	443	493	517	514	483
February	Direct	288	440	562	646	685	678	625
	Diffuse	261	256	243	223	196	164	130
KT = 0.38	Reflected	0	2	7	16	27	41	55
	TOTAL	549	699	813	884	908	883	810
March	Direct	579	746	861	918	912	844	719
	Diffuse	398	391	371	340	298	250	199
KT = 0.46	Reflected	0	3	13	29	49	72	98
	TOTAL	977	1140	1245	1286	1259	1167	1015
April	Direct	875	980	1021	996	905	754	555
	Diffuse	548	539	512	468	411	345	274
KT = 0.49	Reflected	0	5	19	42	71	105	142
	TOTAL	1423	1524	1552	1506	1387	1204	971
May	Direct	1220	1254	1218	1110	935	706	442
	Diffuse	642	631	599	548	482	404	321
KT = 0.53	Reflected	0	6	25	55	93	138	186
	TOTAL	1862	1891	1842	1712	1510	1248	953
June	Direct	1241	1229	1156	1019	826	590	334
	Diffuse	698	686	651	596	523	439	349
KT = 0.52	Reflected	0	7	26	57	97	144	194
	TOTAL	1939	1922	1833	1672	1446	1173	877
July	Direct	1448	1458	1392	1247	1029	755	449
	Diffuse	643	632	600	549	482	405	321
KT = 0.58	Reflected	0	7	28	61	105	155	209
	TOTAL	2091	2097	2020	1856	1615	1314	979

Reflectivity from ground, roof assumed at 20%

		Horiz.	15°	30°	45°	60°	75°	Vert.
August	Direct	1135	1227	1243	1180	1041	837	582
	Diffuse	569	559	530	485	426	358	284
KT = 0.55	Reflected	0	6	23	50	85	126	170
	TOTAL	1703	1791	1796	1715	1553	1321	1036
September	Direct	785	958	1066	1102	1062	950	774
	Diffuse	443	435	413	378	332	279	221
KT = 0.52	Reflected	0	4	16	36	61	91	123
	TOTAL	1228	1398	1496	1516	1456	1320	1118
October	Direct	414	596	737	828	862	838	757
	Diffuse	301	296	281	257	226	190	151
KT = 0.44	Reflected	0	2	10	21	36	53	72
	TOTAL	715	894	1028	1106	1124	1081	979
November	Direct	183	320	435	520	569	580	552
	Diffuse	189	186	176	161	142	119	94
KT = 0.36	Reflected	0	1	5	11	19	28	37
	TOTAL	372	507	616	692	730	727	683
December	Direct	88	173	246	302	337	350	338
	Diffuse	144	141	134	123	108	91	72
KT = 0.29	Reflected	0	1	3	7	12	17	23
	TOTAL	232	315	383	431	457	457	433

AVERAGE DAILY TOTAL INSOLATION FOR SPECIFIC PERIODS (BTU/SF/DAY)
SEATTLE-TACOMA, WASHINGTON

DEC-JAN	256	343	413	462	487	486	458
NOV-MARCH	482	605	698	755	772	747	683
OCT-APRIL	649	777	867	913	910	861	767
MAY-SEPT	1767	1822	1799	1696	1517	1276	992
ALL YEAR	1118	1215	1258	1241	1165	1035	861

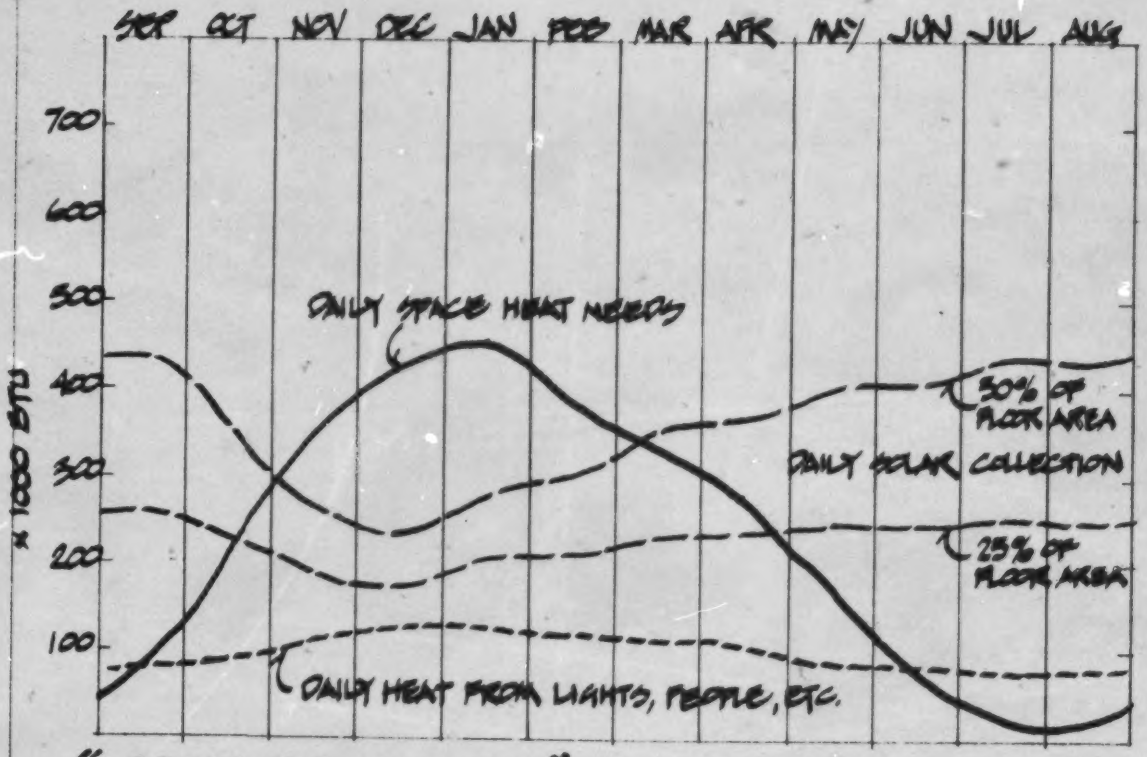
SOLAR ENERGY & SPACE HEATING, WILLAMETTE VALLEY

This illustrates the portion of space heating needs that could be met, on an average daily basis, by solar energy.

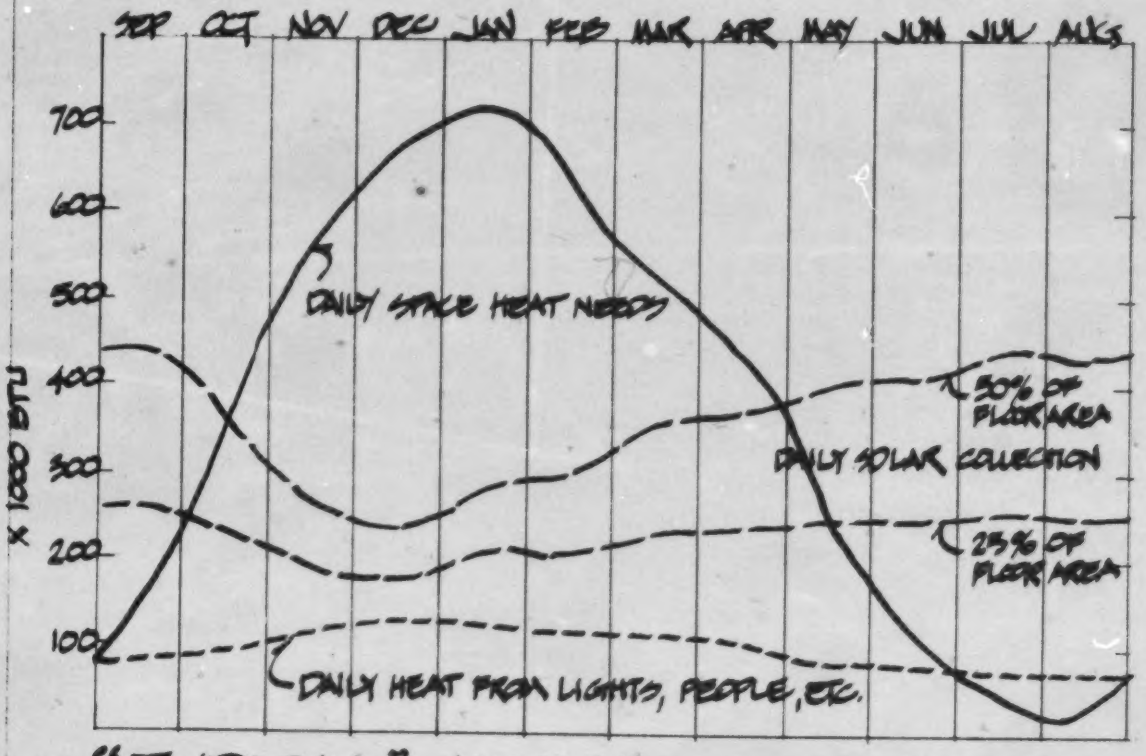
For these examples: Residence of 1500 square feet of heated floor area
Heat Loss at 15°F outside: "CONSERVATION" House, 25 Btuh/sq.ft.
"TYPICAL" House, 40 Btuh/sq.ft. = 1.6 x "Conservation"
Solar Collector: 60° tilt, south facing, 30% efficiency for collecting total radiation
COLLECTOR AREAS: 750 sq.ft. (50% of floor area)
375 sq.ft. (25% of floor area)
NOTE: No reflector

To find Btuh loss per degree day: $\frac{25 \text{ Btu/hr/sq.ft. x 24 hours}}{65^{\circ} \text{ base} - 15^{\circ} \text{ design}}$ = 12 Btu/sq.ft./degree day, "Conservation" house.

AVERAGE DEGREE DAYS Eugene, Ore.			SPACE HEATING NEEDS PER DAY			DAILY HEAT FROM LIGHTS, PEOPLE, ETC.	SOLAR ENERGY COLLECTED PER DAY (Btu) Corvallis, Ore. 8-year average 60° south facing, 30% efficient		
Month	Per Mo.	Per Day	Btu "Conservation" Per Sq.Ft. x 1500 S.F.		"Typical" x 1.6	Btu	Per Sq. Ft.	375 S.F.	750 S.F.
Jan.	766	25	300	450,000	720,000	130,000	206	77,200	154,400
Feb.	597	21	252	378,000	605,000	120,000	230	86,200	172,400
Mar.	574	18.5	222	333,000	533,000	115,000	310	116,100	232,200
Apr.	456	15	180	270,000	432,000	105,000	342	128,100	256,200
May	289	9	108	162,000	259,000	90,000	410	153,700	307,400
June	123	4	48	72,000	115,000	85,000	422	158,200	316,400
July	37	1	12	18,000	29,000	75,000	475	178,000	356,000
Aug.	34	1	12	18,000	29,000	75,000	460	172,400	344,800
Sept.	119	4	48	72,000	115,000	85,000	460	172,400	344,800
Oct.	366	12	144	216,000	346,000	95,000	344	128,900	257,800
Nov.	580	19	228	342,000	547,000	115,000	194	72,700	145,400
Dec.	729	23.5	282	423,000	677,000	130,000	127	47,600	95,200



"CONSERVATION" HOUSE



"TYPICAL" HOUSE

HEATING SEASON PEAK COMPARISONS

In addition to monthly average insolation and heat loss data, a closer look at the daily pattern is necessary for designing solar heat storage. Such an analysis shows a rather close relationship between cold days and clear days.

These charts show the daily relationship between Langleys* of horizontal insolation at Corvallis, degree days* at the Eugene Airport, and megawatts of peak load on the Eugene Water & Electric Board (EWEB) system. Each season is shown from late November to mid-February.

Some observations:

1. Insolation and temperature are not necessarily identical at Eugene Airport and Corvallis (35 miles apart on floor of Willamette Valley).

2. EWEB's system is influenced by weekends and holidays (lower peaks) and Mondays and days after holidays (higher peaks). Eugene is about 60% electrically heated.

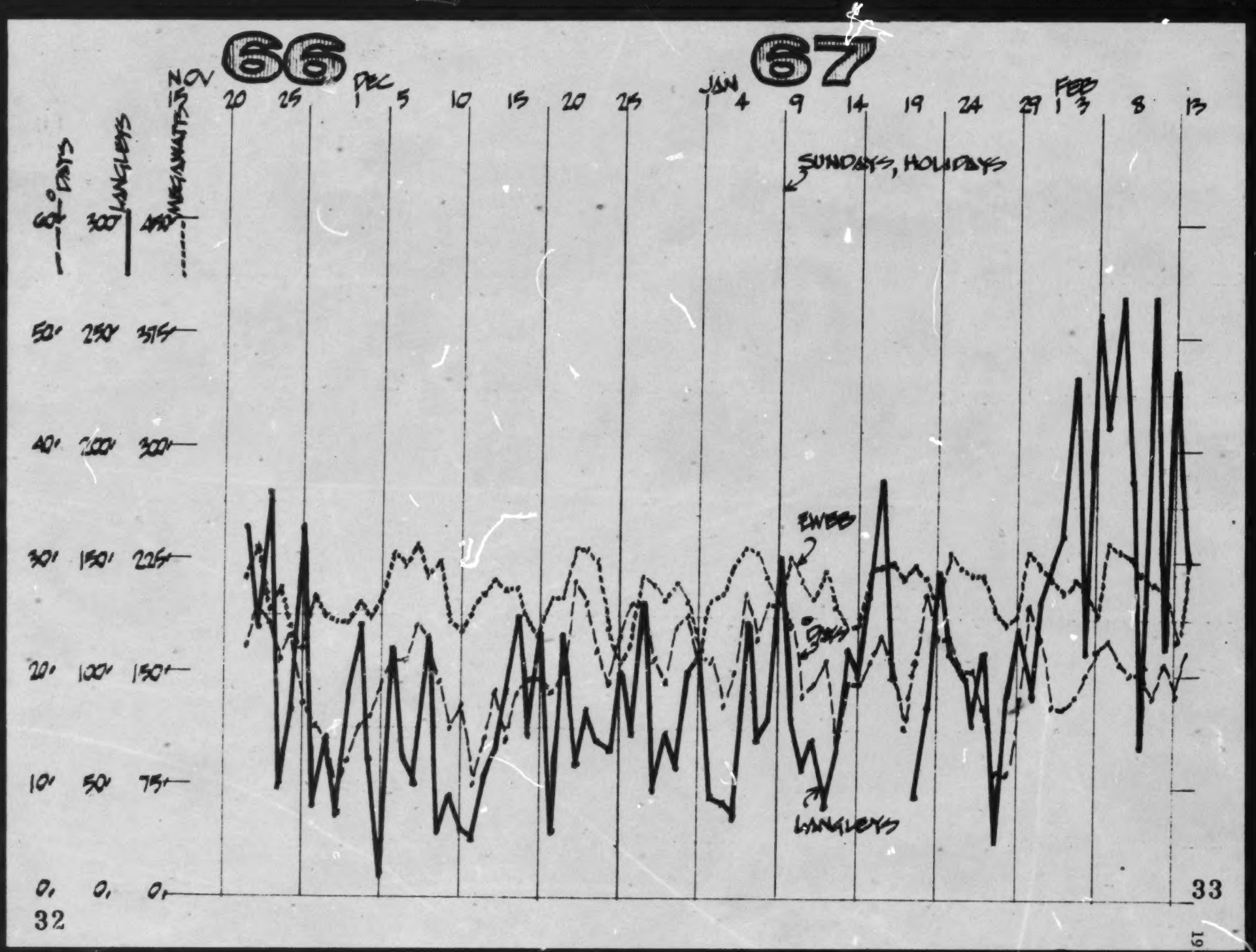
3. If insolation were available as measured on a 45° or 60° south facing surface rather than horizontal, more pronounced peaks and valleys would be expected. This is due to direct sun (peaks) more nearly normal to such tilted surfaces, and diffuse sky radiation (valleys) less nearly normal.

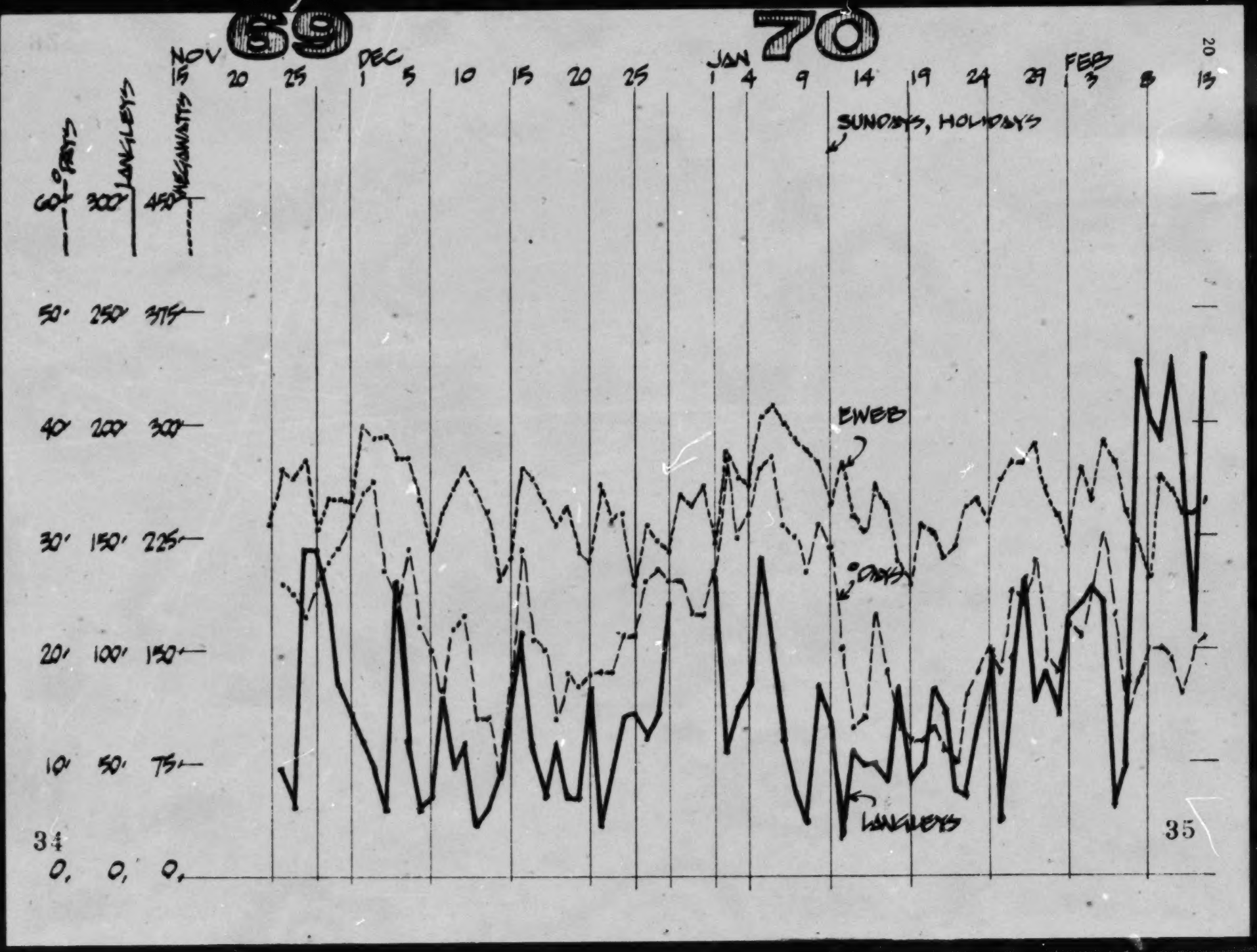
4. The longest consecutive period with very low insolation is a 9 day period in December 1971, during which the outdoor temperature averaged 38°, wind speed averaged about 12 mph, and 6" rain fell in the first 7 days. This seems to represent a "worst condition".

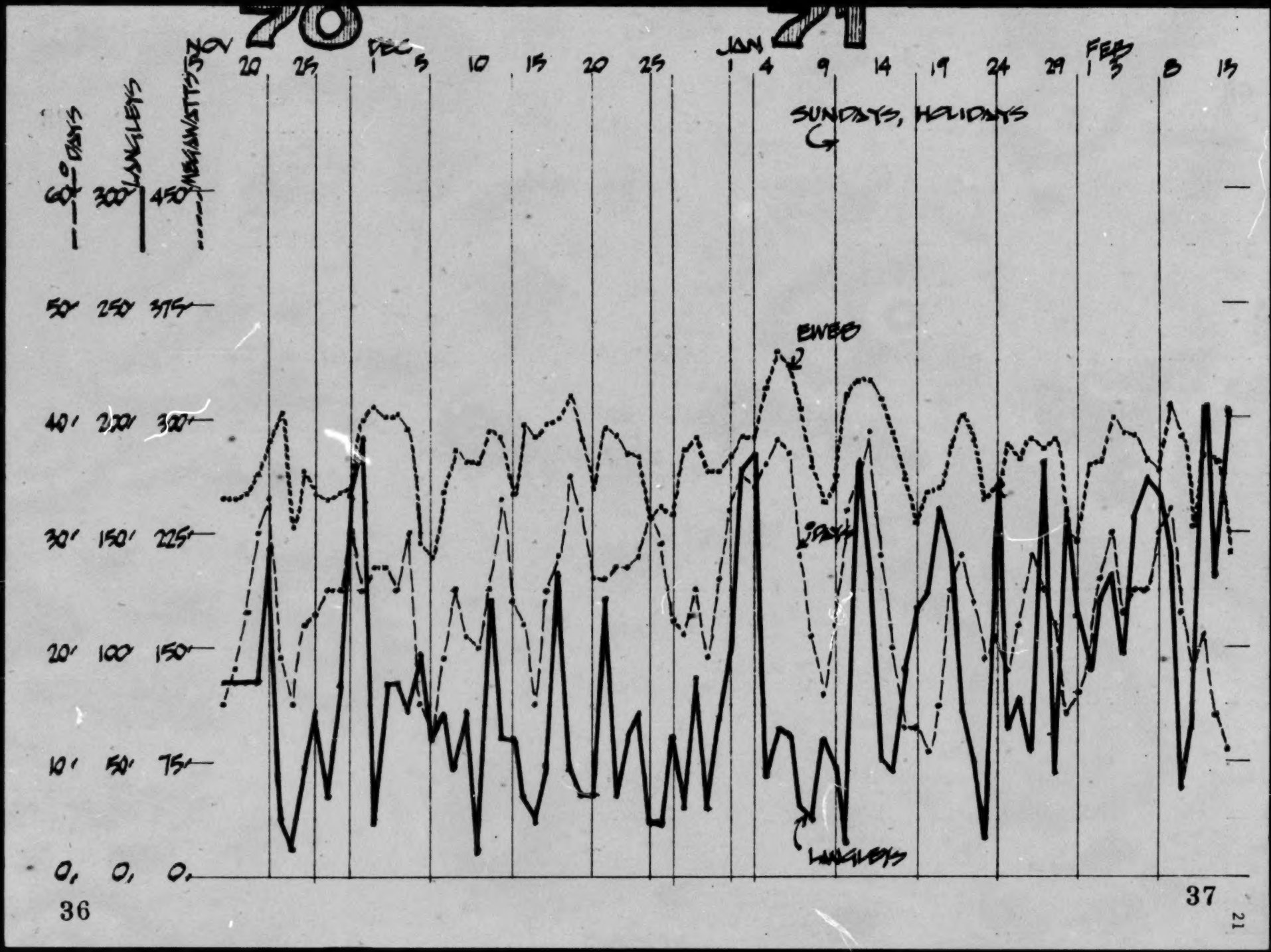
5. The longest consecutive period with high insolation is a 4 day period in February 1970, during which the outdoor temperature averaged 46°, wind speed averaged about 6 mph, and no rain fell (though early morning fog was recorded on the first two days).

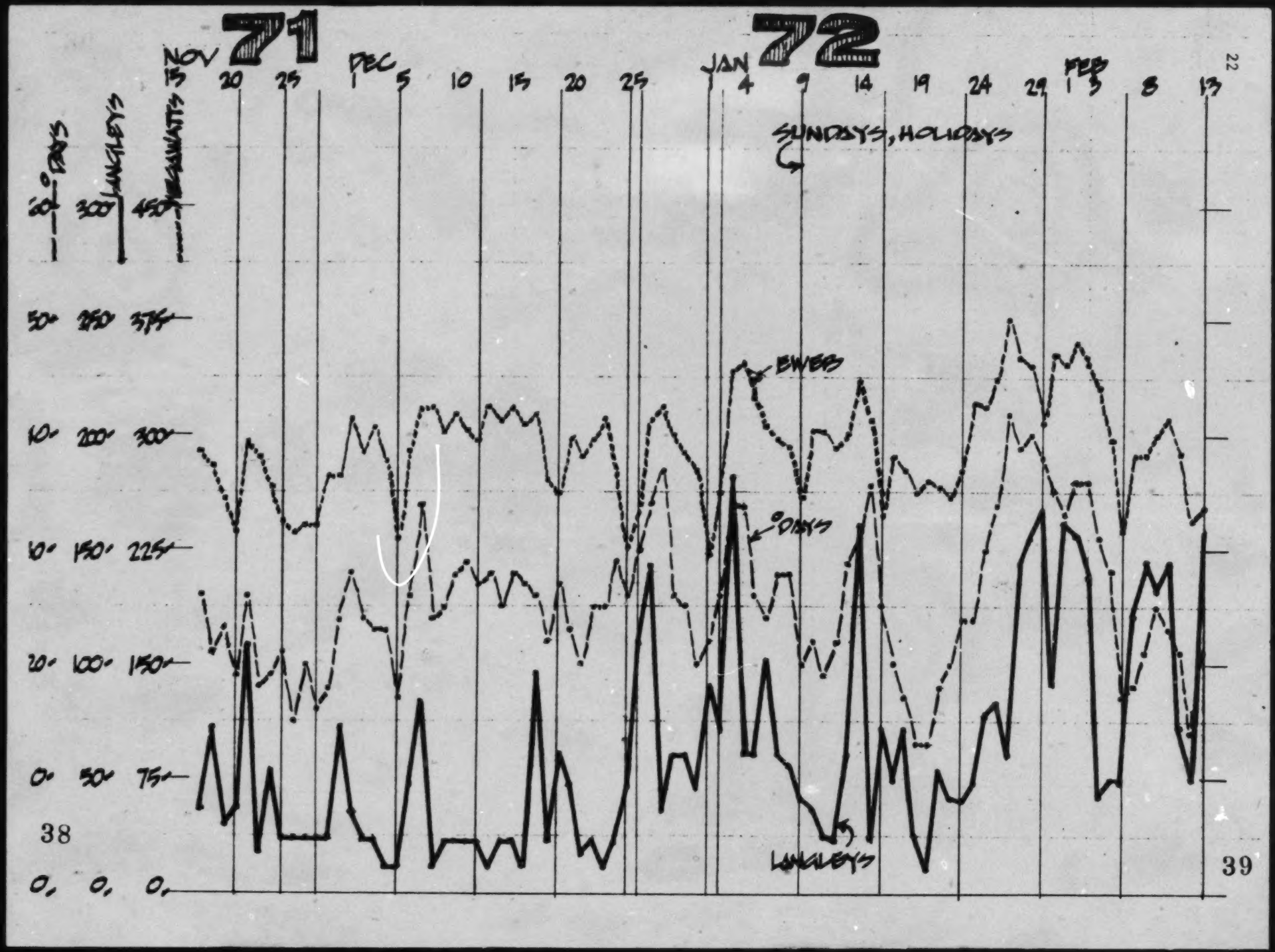
This preliminary comparison indicates a promise of insolation increasing as space heat needs increase, providing both peak-shaving potential for electric utilities and brownout protection for consumers.

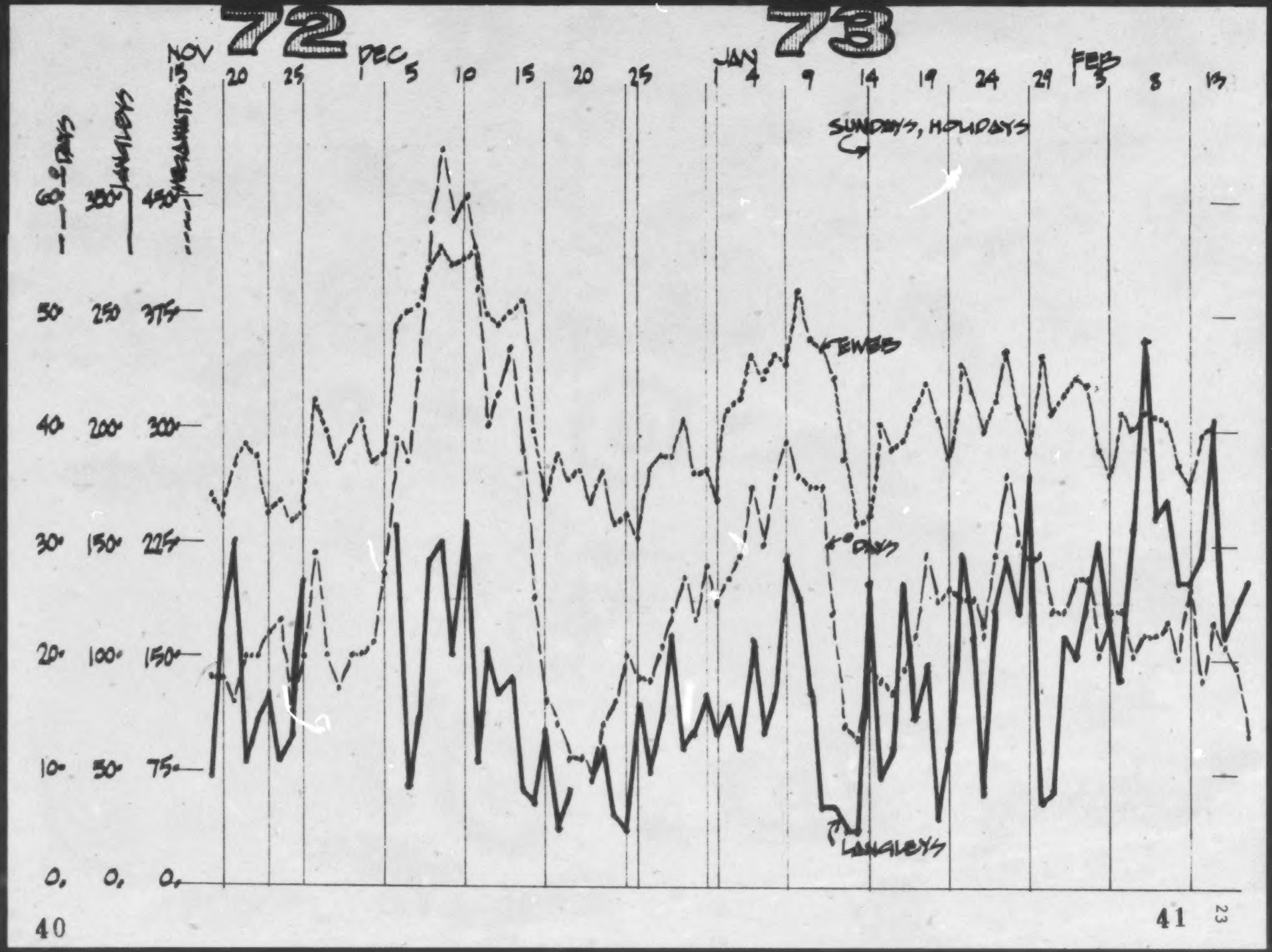
* 1 Langley = 3.687 Btu/sq. ft.; degree days per day are the result of subtracting that day's mean temperature from the base of 65°; the colder the day, the more degree days for that day.


66
67
NOV
DEC
JAN
FEB
20
25
1
5
10
15
20
25
4
9
14
19
24
29
1
3
8
13
SUNDAYS, HOLIDAYS
EWES
LAMBS
WINGLEYS
60° DAYS
300 WINGLEYS
450 EWES/LAMBS
50° 250 375
40° 200 300
30° 150 225
20° 100 150
10° 50 75
0° 0 0
32
33


69
70
NOV
DEC
JAN
FEB
15 20 25 1 5 10 15 20 25 1 4 9 14 19 24 29 3 8 13 20
SUNDAYS, HOLIDAYS
EWEB
CMPS
LANGLEYS
60° DAYS
300 LANGLEYS
450 WESTWARDS
50° 250 375
40° 200 300
30° 150 225
20° 100 150
10° 50 75
0° 0 0
34
35


78
DEC
JAN
71
FEB
20 25 1 5 10 15 20 25 1 4 9 14 19 24 29 1 5 8 15
SUNDAYS, HOLIDAYS
60° DAYS
300 LANGLEYS
450 MEGAWATTS SZ
50 250 375
40 200 300
30 150 225
20 100 150
10 50 75
0 0 0
EWEB
LANGLEYS
36
37
21


71
72
NOV
DEC
JAN
FEB
15 20 25 1 5 10 15 20 25 1 4 9 14 19 24 29 1 3 8 13
SUNDAYS, HOLIDAYS
EWES
LAMBS
LAMBS
SUNDAYS
20 300 450
50 250 375
10 200 300
10 150 225
20 100 150
0 50 75
0 0 0
38
39


72
DEC
73
JAN
FEB
NOV
20 25 1 5 10 15 20 25 1 4 9 14 19 24 29 1 5 8 13
SUNDAYS, HOLIDAYS
TEMPS
DAYS
LANGLEYS
60 50 40 30 20 10 0
350 250 200 150 100 50 0
450 375 300 225 150 75 0

PACIFIC NORTHWEST SOLAR HEATING SUMMARY

Some Conversion Factors:

1 Langley = 3.687 Btu/sq.ft. = 1 calorie/sq.cm.

1 cu.ft. water (at 60°F) = 62.37 lb = 7.481 gallons = .02832 cu. meters

1 Kilowatthour = 3,413 Btu

1 sq.ft. = .0929 sq. meters

1 Horsepower = 745 watts = 42.4 Btu/minute

A Possible Design Procedure: (with many retraced steps advisable!)

Follow up on the references in the bibliography; inform yourself.

Get the best available local solar and weather data.

Analyse your site for optimum collector location (see sun charts and explanation).

Hire an architect, engineer or builder (if you plan to use them eventually, this is a good time to initiate talks).

Calculate your total heating needs (see Solar energy/space heating for rough data).

The more insulation and double glazed windows you buy, the less collector/storage capacity you'll need.

Subtract that portion of heat which comes from sun through windows, cooking, etc. (see also the yearly analysis of Mathew house, Coos Bay).

Choose your system: water, air, another medium, combinations of same, etc.

Find optimum collector and storage sizes; an involved mix of insolation, heat needs, consecutive cloudy days (see Peak Comparisons), and future interest and utility rates.

Choose and size the auxiliary heat supply.

Decide extent to which collector and storage are to be integrated with your building.

Get manufacturers data on collector materials, pumps and controls, storage tanks, etc. (source: Lee Johnson, OMSI Energy Center, Portland, Oregon).

RULES OF THUMB

These "rules-of-thumb" should be regarded as very tentative, being based on several information sources from widely varying locales and points in time. They are for preliminary planning only, and subject to change.

Assumed Heating Needs: (Where average winter day temperature = 45°F)

"typical" house: 440 Btu/S.F. floor area/day (loses 40 Btu/s.f. @ 15° outdoors)

"conservation" house: 280 Btu/s.f. floor area/day (loses 25 Btu/s.f. @ 15° outdoors)

Collector Efficiency (using window glass and simple black paint surfaces)

** % of all solar radiation collected: 20-33%
** % of all solar radiation collected while operating: 30-40%

Note: For a south facing 60° tilt collector, Willamette Valley, January:
663 Btu/s.f./day is incident on collector, average;
625 Btu/s.f./day is incident during "ideal" operating hours only.
Therefore, from 133 Btu/s.f. to 250 Btu/s.f. could be considered collectable, in this instance.

Collector Tilt Angle to Horizontal (South-facing):
(The presence of a reflector is not considered beyond 20% reflectivity assumed in calculations)

For November-March optimum: 45° to 60°
For October-April optimum: 45° to 60°
For yearly total optimum: 15° to 30°

Collector Area

*For domestic water heating only: 25 sq. ft. per person (up to 40 s.f./person for near-100% solar water heating).

For space heating in residences (entire heating season):
to obtain about 40% from sun: collector area = 25-35% of floor area
to obtain about 80% from sun: collector area = 50-60% of floor area
(Yet, Coos Bay Solar House got up to 75% with a collector area only 25% of floor area, aided by reflector)

Flow Rate Through Collector

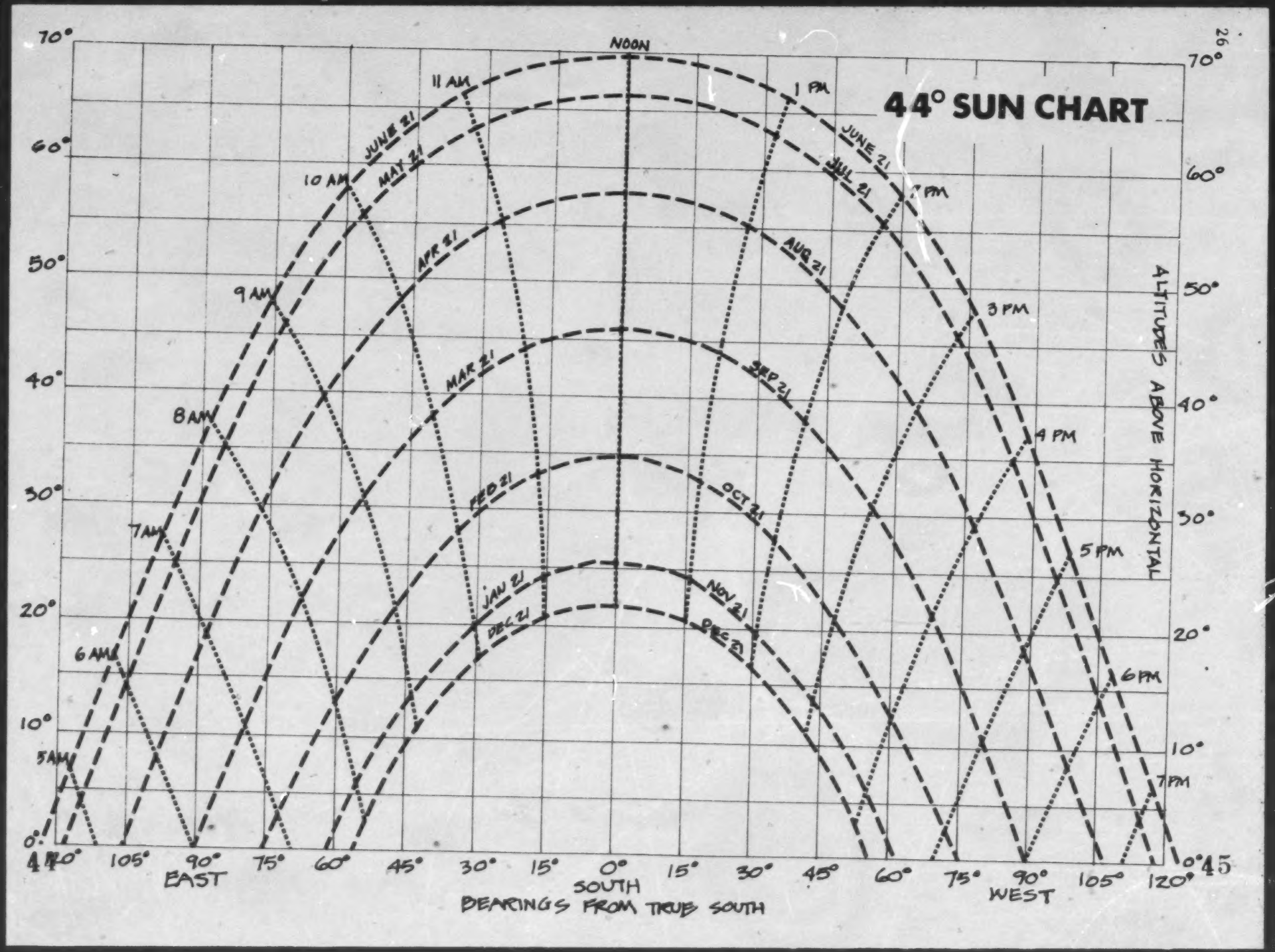
*Water: 1 gallon/hr./sq.ft. of collector area
*Air: 25 lbs/hr./sq.ft. of collector area

Storage Tank Size (water):

*7 gallons water per square ft. collector area (but Coos Bay example had 20 gal./s.f., now has 11 gal/s.f.
Domestic water heating only: 300 gallons total.

*A. Whillier, "Principles of Solar House Desig...", Progressive Architecture 36:122-6, May, 1955.

**G. Löf, "General Report: Use of Solar Energy for Heating Purposes: Space Heating," U.N. Conference on New Sources of Energy, Rome 1961, Vol.5,p.114 on.


44° SUN CHART
NOON
11 AM
1 PM
10 AM
2 PM
9 AM
3 PM
8 AM
4 PM
7 AM
5 PM
6 AM
6 PM
5 AM
7 PM
JUNE 21
MAY 21
APR 21
MAR 21
FEB 21
JAN 21
DEC 21
JUNE 21
JUL 21
AUG 21
SEP 21
OCT 21
NOV 21
DEC 21
70°
60°
50°
40°
30°
20°
10°
0°
ALTITUDES ABOVE HORIZONTAL
120° 105° 90° 75° 60° 45° 30° 15° 0° 15° 30° 45° 60° 75° 90° 105° 120°
EAST
SOUTH
WEST
BEARINGS FROM TRUE SOUTH

ANALYZING A SITE FOR SOLAR COLLECTOR SUITABILITY

First, explore the site to determine which location has the best combination of open view towards due south, and open view of the entire sky dome. If the skyline is low, that is with no tall trees, adjacent buildings, abruptly rising hills, or other obstructions, the following procedure is unnecessary.

Now, place yourself at the approximate center of where you think the collector will be. This may require a ladder, as many collectors are part of the roof system.

Using : a compass for bearing readings
: a surveyor's hand level for altitude readings
: a pencil and the "44° sun chart";

Find the altitude of the skyline as follows:

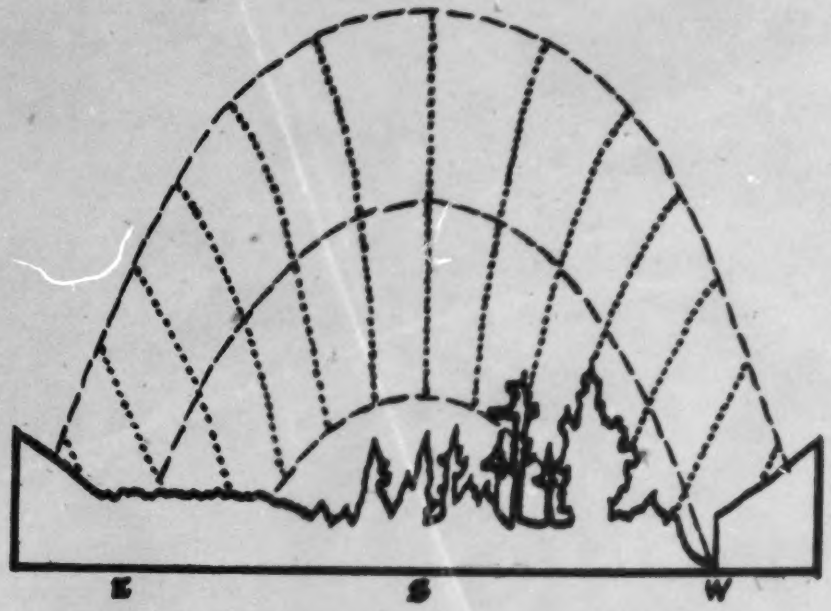
Determine which direction (bearing) is due south. (Due south will be about 21° east of magnetic south in the Willamette Valley.)

Aiming your hand level due south, determine the altitude (angle above the horizontal) of the skyline. On the chart, write this angle below "0° SOUTH" on the scale of bearings at the bottom of the chart.

Similarly, find and record the altitudes of skyline for each 15° bearing, both east and west of south, to at least 105°. (This is a total of 15 altitude readings.)

For isolated objects such as tall trees, find both the bearing and the altitude for each object, and record at appropriate bearing.

Plot these altitude readings for their respective bearings on the 44° sun chart, and connect them. Result: your skyline.



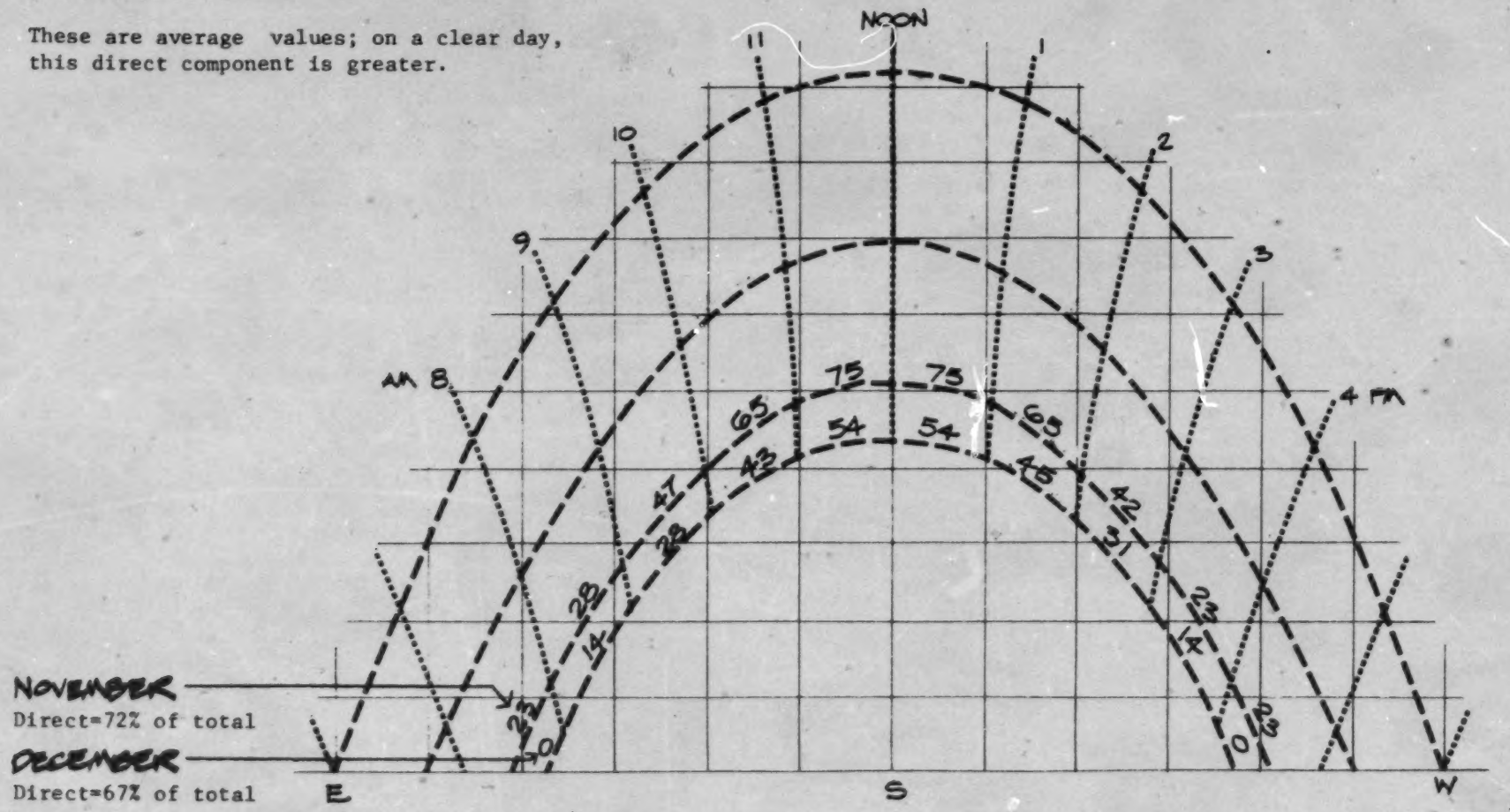
"SKYLINE" FROM MATHEW SOLAR HOUSE, COOS BAY
From center of collector on roof, in 1974

EVALUATING OBSTRUCTIONS TO WINTER SUN

The direct component of winter insolation will of course be lost whenever the sun is blocked from the collector.

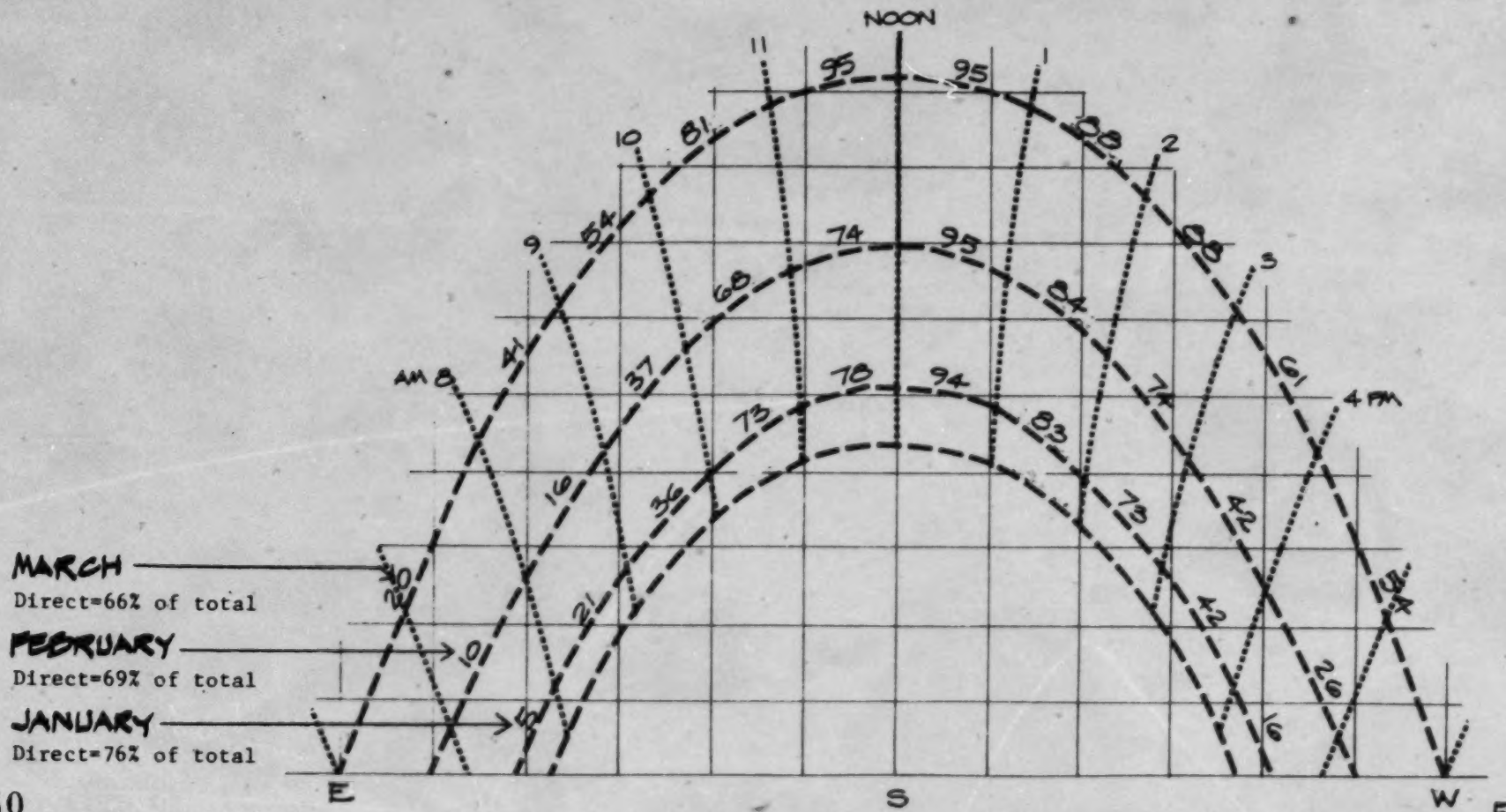
The hourly total Btu/sq. ft. direct insolation incident on a 60° tilted surface, based on 5-year horizontal averages at Corvallis, are shown for the five coldest winter months.

These are average values; on a clear day, this direct component is greater.



Note that November and December average insolation (above) is fairly evenly divided between morning and afternoon, but later in winter (below) the average afternoon insolation is greater than in the morning.

A "timetable" for horizontal insolation is shown on page 32.



PRELIMINARY SIZING OF YOUR COLLECTOR AND STORAGE TANK

If the "rules of thumb" listed a few pages back give extremely rough results, then this procedure can be considered to give moderately rough answers to solar heating sizing questions. This procedure utilizes data from several sections of this book: Corvallis insolation on tilted surfaces, Peak comparisons between insolation and temperature (for storage tank "number of days" judgments), Eugene climate "time-tables" (Part 3), and still more rules of thumb on residential heat loss and gain.

1 WINTER DESIGN HEAT LOSS (Btu/H)

Two Alternate Methods (for worst winter hour)

1. Calculation of heat loss (see an engineering text-reference)

$\sum(U)(Area)(\Delta T)$ = _____ Btu/H

or

2. Estimation of heat loss

(_____ Floor Area, ft^2)(_____ Loss Estimate) = _____ Btu/H

Loss Estimate: 'Conserving House'..... 25 Btu/H/ft^2
'Typical House'..... 40 Btu/H/ft^2

2 WINTER AVERAGE DAILY HEAT LOSS (Btu/Day)

$$\frac{(___\text{Btu/H})(24\text{ hr})(___^{o}\text{Room Temp} - ___^{o}\text{Avg Wint Temp}}{(___^{o}\text{ Room Temp} - ___^{o}\text{ Wint Design Temp})} = ___\text{Btu/Day}$$

Heat Gain from appliances, lights, people, solar window gain
= 100,000 to 130,000 Btu/Day

_____ Btu/Day (Heat Loss) − 100,000 Btu/Day (Heat Gain) = _____ Btu/Day (Heat needed)

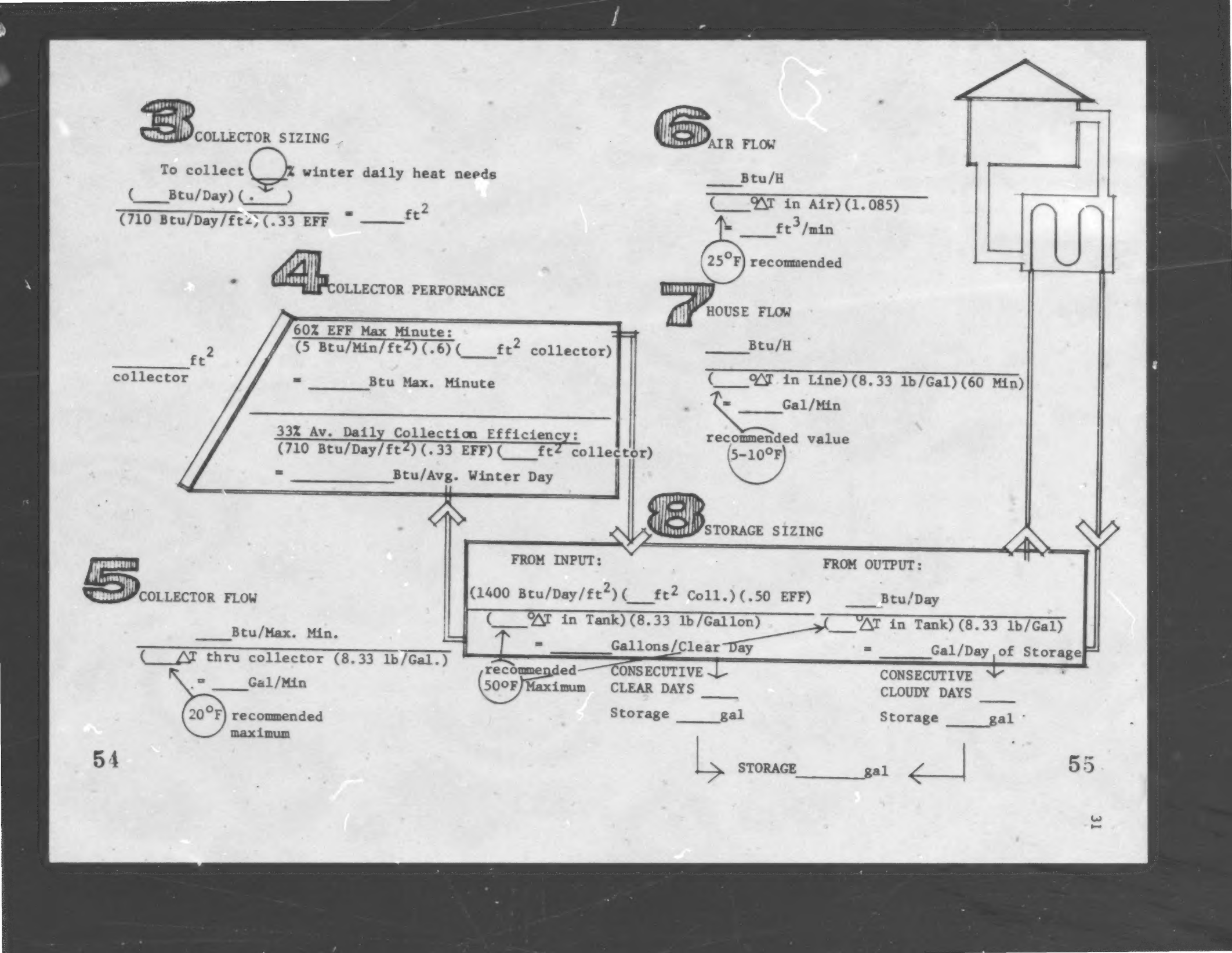
NOTE: In step 3, you will estimate what % of your winter daily heat needs you intend to collect. Be sure to then do a more detailed month-by-month analysis, using your collector size and insolation data for your area, as was done in the "Solar Energy & Space Heating" analysis, pages 16, 17. This analysis may yield a different, but more accurate % of winter heat needs.

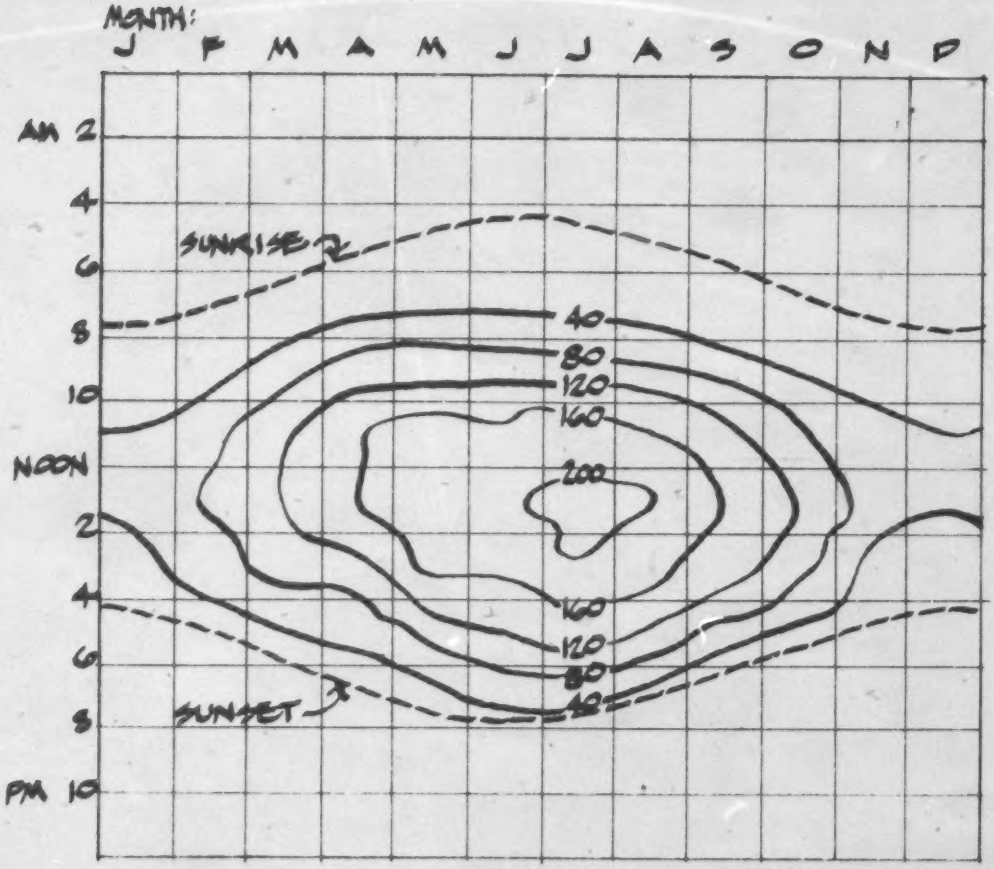
EUGENE CLIMATIC & SOLAR INSOLATION DATA

Winter Design Temp ..... 15°F
Average Winter Temp (Nov-Mar) ..... 44°F
Room Temp: .....typically 65-70°F
Insolation: South-facing slopes:

	60° tilt:	Vertical, with reflector*
Average Winter Day (Nov-Mar)	710 Btu/Day/ft^2	... 935
Maximum Winter Day	1400 Btu/Day/ft^2	... 1940
Maximum Minute	5 Btu/min/ft^2	... 7

(*Reflector north-south dimension = 2 or more times the height of collector)


3 COLLECTOR SIZING
To collect ( )% winter daily heat needs
(____Btu/Day)(.____)
(710 Btu/Day/ft²)(.33 EFF = _____ft²
4 COLLECTOR PERFORMANCE
_____ft²
collector
60% EFF Max Minute:
(5 Btu/Min/ft²)(.6)(____ft² collector)
= _____Btu Max. Minute
33% Av. Daily Collection Efficiency:
(710 Btu/Day/ft²)(.33 EFF)(____ft² collector)
= _____Btu/Avg. Winter Day
5 COLLECTOR FLOW
____Btu/Max. Min.
(____ΔT thru collector (8.33 lb/Gal.)
= ____Gal/Min
20°F recommended maximum
6 AIR FLOW
____Btu/H
(____°ΔT in Air)(1.085)
= ____ft³/min
25°F recommended
7 HOUSE FLOW
_____Btu/H
(____°ΔT in Line)(8.33 lb/Gal)(60 Min)
= _____Gal/Min
recommended value
5-10°F
8 STORAGE SIZING
FROM INPUT:
(1400 Btu/Day/ft²)(___ft² Coll.)(.50 EFF)
(____°ΔT in Tank)(8.33 lb/Gallon)
= _____Gallons/Clear Day
recommended 50°F Maximum
CONSECUTIVE CLEAR DAYS ____
Storage _____gal
FROM OUTPUT:
____Btu/Day
(____°ΔT in Tank)(8.33 lb/Gal)
= _____Gal/Day of Storage
CONSECUTIVE CLOUDY DAYS ____
Storage _____gal
STORAGE_____gal
54
55
31



TIMETABLE FOR HORIZONTAL INSOLATION: CORVALLIS, OREGON
BTU/SQ.FT./HOUR

Is daily insolation symmetrical: greatest at noon, and equally strong in the morning and afternoon? The above "timetable" (see explanation of this format in Part Three) represents approximate hourly insolation, plotted every other hour and every other day, for a 5-year average at Corvallis.

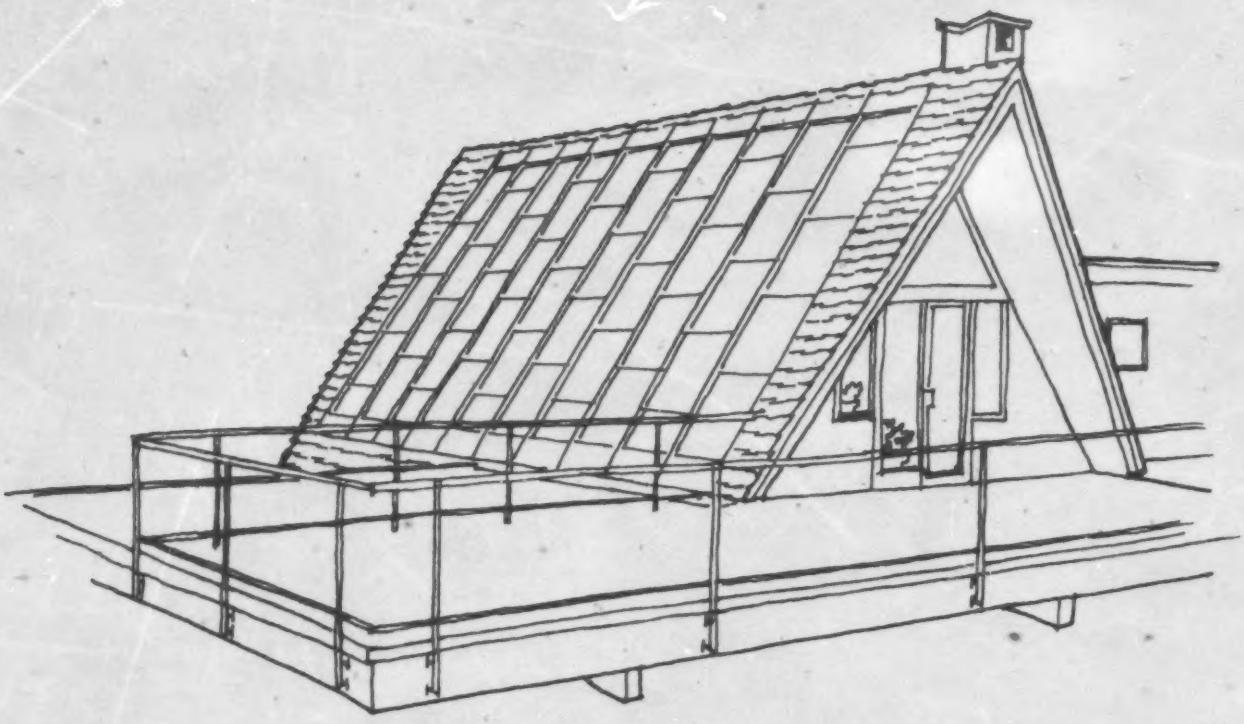
From studying the sun charts, symmetrical insolation (especially in the clearer summer months) would be expected; yet the closest months to symmetry are December, then November. In the months following January, afternoon insolation is stronger than morning insolation; this departure from symmetry seems greatest in the clearer summer months of July and August.

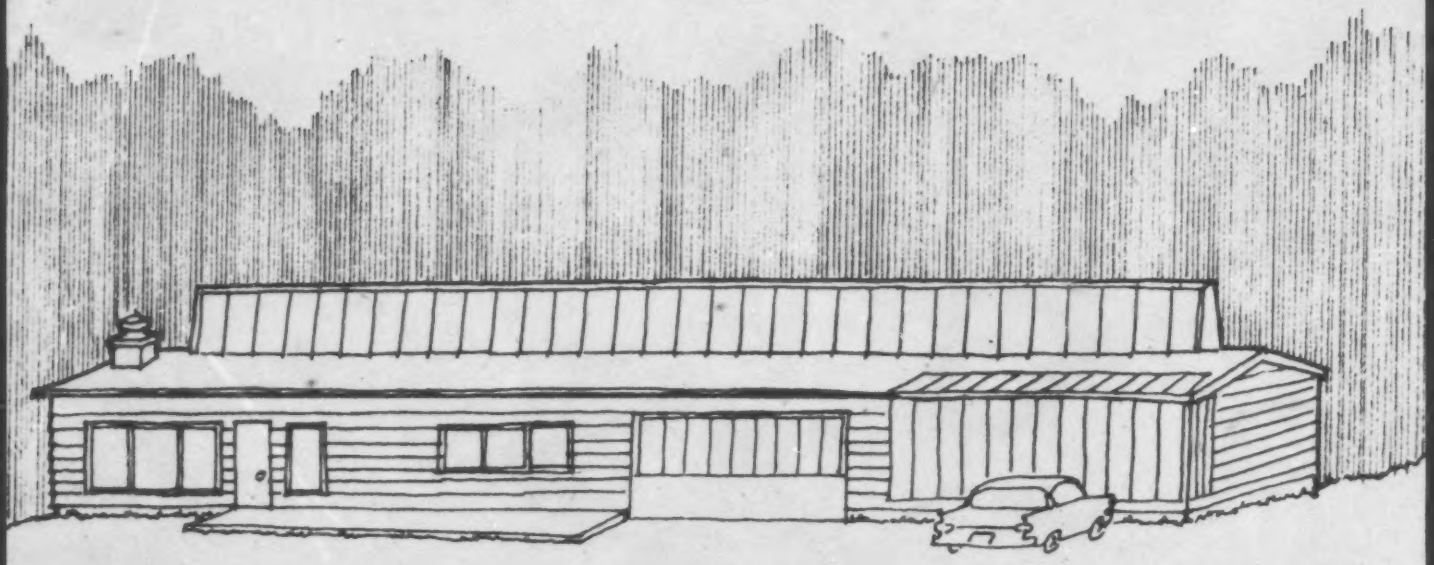
From this data, it is not yet certain that a south-facing collector should be oriented somewhat west of south, although both storage in early fall and utilization in late winter would seem to be improved by such an orientation shift.

PART TWO: NORTHWEST SOLAR HOUSES

Two of the earliest solar collector houses in the Pacific Northwest are discussed here; both are lived in by their designer-builder-owners. In both cases, experimentation on collectors preceded the design of the house. These two houses are nearly identical in size, but the sizes and the geometry of their solar collector/storage systems are quite different.

Many solar houses and some commercial buildings are now completed, under construction or in the design stage. A Guide to Northwest Solar Buildings, kept looseleaf to encourage frequent additions, is needed.





HOFFMANN HOUSE: SURREY, BRITISH COLUMBIA

Built 1967 to 1969, this A-frame house is approximately 50% solar-heated by a double glazed collector, 16' x 30', on the south face of the roof. The collector also preheats domestic hot water, and keeps a small above-ground swimming pool warm all summer. No publication of details, beyond those on the next pages, is yet available, but correspondence may be addressed to:

Erich Hoffman, Professional Engineer
5511 128th Street
Surrey, B.C., CANADA

Mr. Hoffmann works for a Vancouver, B.C., architectural firm.

MATHEW HOUSE: COOS BAY, OREGON

Built in 1967, this unique combination of near-vertical single-glazed collector (5' x 80') and near-horizontal reflector has provided approximately 65% of the space and water heating for the house.

In January 1974, Mr. Mathew added another 325 sq.ft. collector, free standing behind the house, with a small reflector. It appears that the total of 725 sq.ft. of collector provided approximately 80% of the space and water heating for the house in 1974.

A 14-page booklet of details of this house's system is now available from its designer-builder-owner:

Henry Mathew
Route 3, Box 768
Coos Bay, Oregon 97420
Cost: $10

An analysis of the house's performance in the 1974-75 heating season, "The Atypical Mathew Solar House", is also available from the Center for Environmental Research ($1.00).

Following is a comparison between these and several other well-known solar houses; a description of the basic systems; and some additional details of KWH and dollar savings on the Mathew house at Coos Bay.

A COMPARISON OF TWO PACIFIC NORTHWEST SOLAR HOUSES

	Mathew Residence Coos Bay, Oregon	Hoffmann Residence Surrey, British Columbia
Latitude	43°N	49°N
Altitude	about 50 ft.	75 feet
Average degree days	4600	5500
January solar intensity (langleys/day)	approximately 95 (1975:90)	unknown
Minimum design temperature	about 20°F	11°F
Floor area, heated	1620 ft^2	1450 ft^2
Collector:		
Transfer fluid	water	water
Tilt (south facing)	82°,with reflector	58°
Area	400 ft^2 primary, 325 ft^2 secondary	460 ft^2
Heat transfer surface	galvanized steel pipes wired to aluminum sheet	copper tubes soldered to copper sheet
Glazing	single glass	two sheets glass
Auxiliary Heat:	Portable Electric Resistance	Electric Baseboard
Storage:		
Type	Water	Water
Volume	8,000 gal.	810 gal.
Normal Maximum Temperature	150°F	170°F
% Load supplied by solar heat	est. 60% to 75%, primary only; est. 80% primary + secondary	est. 50%
Transfer of heat to rooms	Gravity air circulation around tank, and warmed floor over crawl space	Gravity air circulation around tank. (Future forced air)

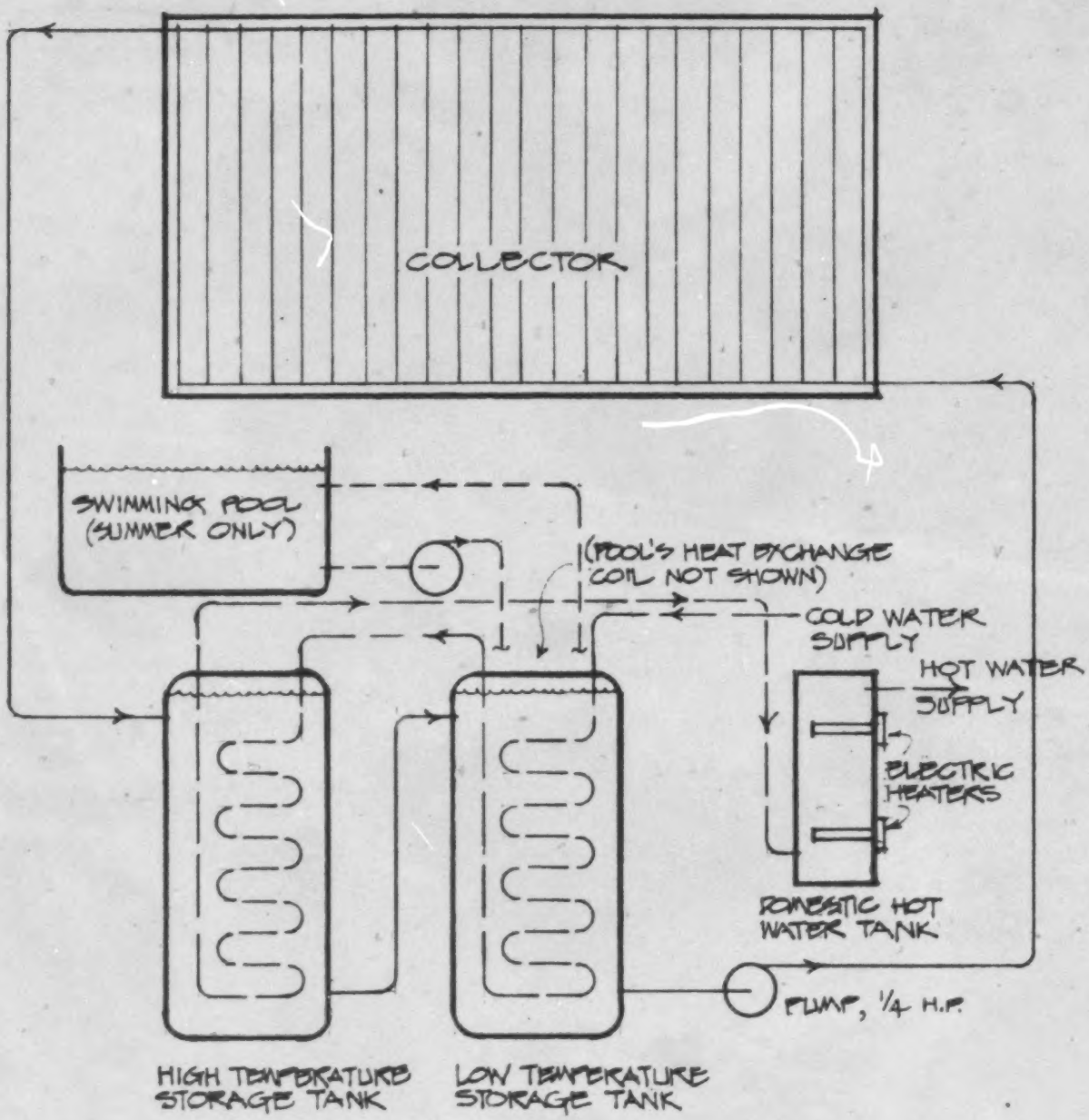
WITH SOME WELL-KNOWN SOLAR HOUSES ELSEWHERE

Thomason House #1 District of Columbia	M.I.T. Solar House IV Massachusetts	Löf Residence Englewood, Colorado
39° N	42° N	40° N
about 50 ft.	about 200 ft.	5400 ft.
4300	6000	6100
160	160	220
13° F	-10° F	0° F
1500 ft^2	1450 ft^2	3200 ft^2
water	water	air
60° wall, 45° roof	60°	45°
840 ft^2	640 ft^2	600 ft^2
corrugated sheet metal	copper tubes on aluminum sheet	overlapped glass plates
plastic and glass	double glass	3 to 4 sheets of glass
Oil Furnace	Oil Furnace	Natural Gas Furnace
water and rocks	water	rocks
1600 gal. water	1500 gal.	250 cu. ft.
125° F to 135° F	about 120° F	140° F
est. 90%	56.8%	26.5%
Forced air circulation through rocks around tank	Heat exchange to air	Forced air through rocks

(Data this page from Löf's summary, Vol. 5, U.N. Conference on New Sources of Energy, Rome 1961)

HOFFMANN SOLAR HOUSE

SURREY, BRITISH COLUMBIA

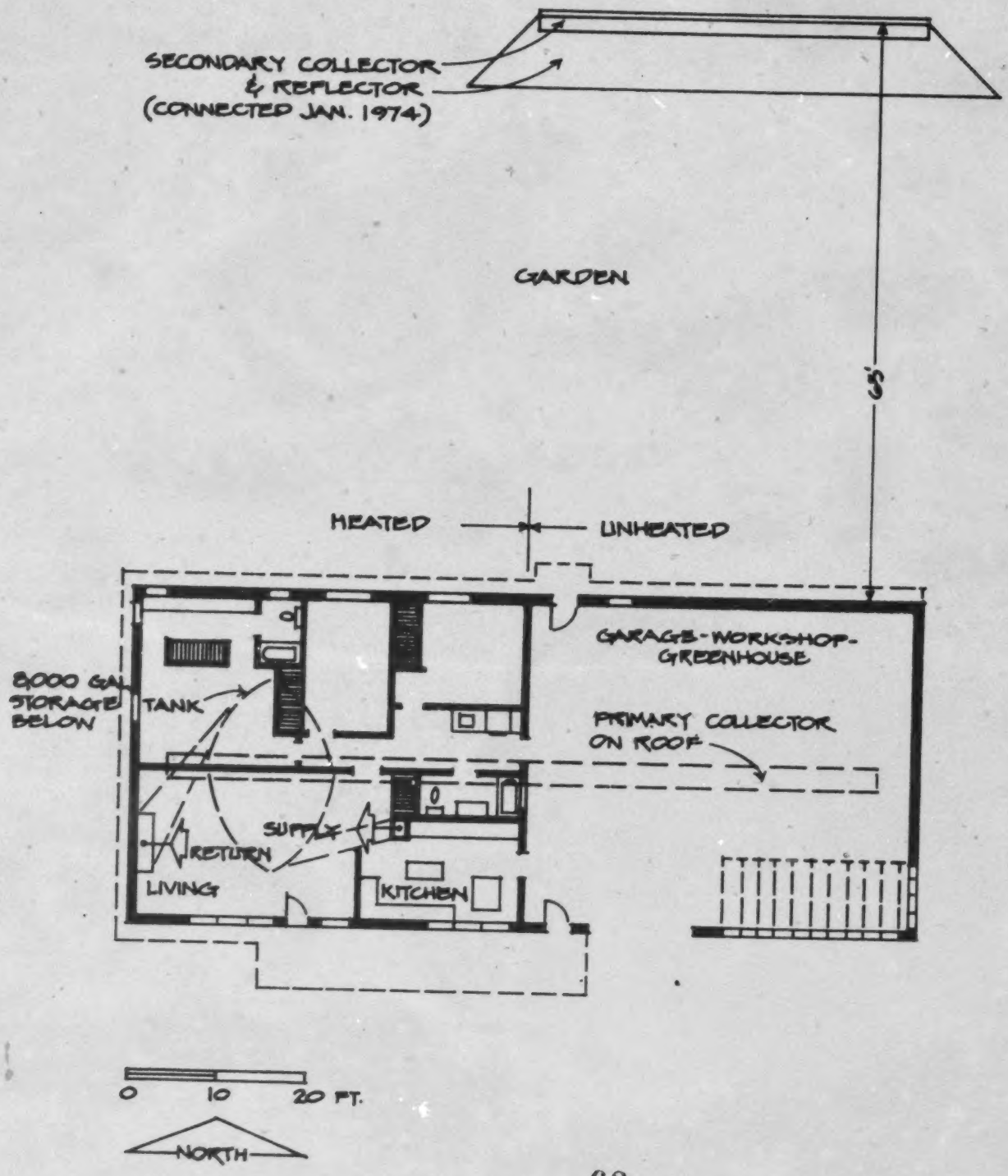


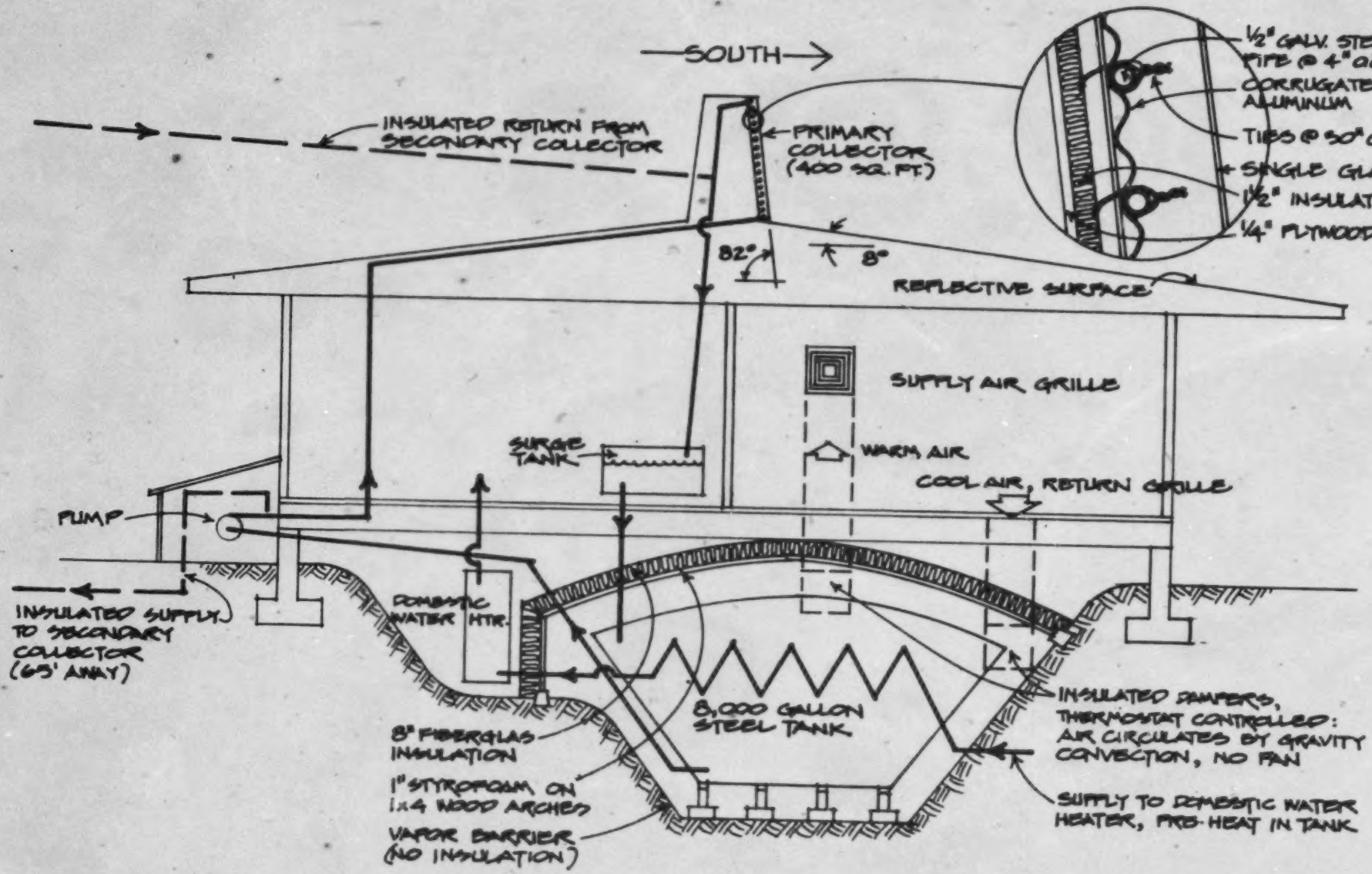
SOLAR HEATING FLOW SHEET

SYSTEM DESIGNED 1967 BY ERICH HOFFMANN (NO SCALE)

MATHEW SOLAR HOUSE

COOS BAY, OREGON
DESIGNED & BUILT BY HENRY MATHEW, 1967





MATHEW SOLAR HOUSE

COOS BAY, OREGON

APPROXIMATE YEARLY HEATING DATA: Mathew Residence, Coos Bay, Oregon

Heat Loss Standard Computation by Pacific Power & Light Company

At $\triangle T = 50$ ($70^{\circ} - 20^{\circ}$), MATHEW RESIDENCE LOSSES = 50,020 BTUH = 11.7 KW

TO DETERMINE KWH EXPECTED FOR SPACE HEATING, PPL FORMULA IS:

$$\frac{11.7 \text{ KW} \times \text{Degree Days Yearly} \times 15^{*}}{50^{\circ} \text{ F}} = \text{KWH SPACE HEATING ONLY, YEARLY}$$

*To determine total house heating, this number would be 24 (hours/day); the contribution of other heat sources (electric appliances, lights, people, sun) drops the load on the actual "space heating" system to 15, by PPL estimates, for a typical Oregon customer.

To compare the actual Kwh used for space heating in the Mathew Residence, it is necessary to subtract from the yearly total Kwh that amount used for the other purposes mentioned above.

The Eugene Water and Electric Board assumes a residential average of 1,350 Kwh per month for non-space-heating purposes, while PPL/Coos Bay averages 990 Kwh. Actual measurement of other-than-space-heat loads at the Mathew Residence showed 917 Kwh average per month in 1974. This (probably conservative) total of 11,000 Kwh yearly is used in the table following.

Year	Expected Kwh Space Heating	Actual Tot Kwh Minus 11,000 Kwh	Kwh Saved	Approx. $ Saved	%Space Heating: Electric	%Space Heating: Solar Collection and Energy Conservation	Comments
1970	$\frac{11.7 \times 4596 \times 15}{50} = 16{,}110$	3,213	12,897	$146	20%	80%	1970: 1.2¢/Kwh increased to 1.34¢/Kwh in November.
1971	$\frac{11.7 \times 4763 \times 15}{50} = 16{,}700$	5,827	10,873	$145	35%	65%	
1972	$\frac{11.7 \times 4783 \times 15}{50} = 16{,}700$	8,107 (adjusted, 5,707)	(adjusted, 11,063	$148	48% 34%	52% (adjusted) 66%)	1972: unusually high summer Kwh usage due to 6-month increase (by 4 people) in family size.
1973	$\frac{11.7 \times 4011 \times 15}{50} = 14{,}080$	6,625	7,455	$100	47%	53%	1973: an unusually mild but cloudy winter.
1974	$\frac{11.7 \times 4827 \times 15}{50} = 16{,}950$	2,820	14,130	$200	17%	83%	1974: collector area nearly doubled in January 1974; 1.34¢/Kwh increased to 1.54¢/Kwh in September.
1975	$\frac{11.7 \times 4939 \times 15}{50} = 17{,}300$	2,128	15,172	$239	12%	88%	1975: unusually cold spring. 1.54¢ increased to 1.63¢, mid-August.

SOLAR ENERGY IN ARCHITECTURE

A Selected Bibliography, compiled February 1976

Books

DANIELS, Farrington "Direct Use of the Sun's Energy", Yale University Press, 1970.

DUFFIE, J.A. and BECKMAN, W.A. "Solar Energy Thermal Processes", Wiley & Sons, 1974.

ERWAY, D.D. and ZAREM, A.M. (eds.) "Introduction to the Utilization of Solar Energy", McGraw-Hill, 1963. (Chapter by George Löf, "The Heating and Cooling of Buildings with Solar Energy".)

GRAY, Robert and BAKER, Stephen "Solar Building Survey", Center for Environmental Research, University of Oregon, 1974.

NASA/AUBURN UNIVERSITY "TERRASTAR: Terrestial Application of Solar Technology and Research", NASA, CR-129012, 1973.

OFFICE OF ENERGY RESEARCH AND PLANNING, State of Oregon, "Transition", (A report to the Oregon Energy Council), 1975. (This contains net energy analyses of major energy sources, including solar space heating.)

OLGYAY, Victor "Design With Climate" Princeton University Press, 1963.

SHURCLIFF, W.A. "Solar Heated Buildings: A Brief Survey" 19 Appleton Street, Cambridge, Massachusetts 02138.

THOMASON and THOMASON "Solar House Heating and Air Conditioning Systems" Edmund Scientific, 1974.

UNITED NATIONS "Proceedings of the U.N. Conference on New Sources of Energy, Rome 1961" (Volume 5: Solar Energy for Heating).

Periodicals

"Advanced Solar Energy Technology Newsletter", 1609 West Windrose, Phoenix, Arizona 85029.

"Alternative Sources of Energy", Rt. 2, Box 90A, Milaca, Minnesota 56353.

"Solar Energy", Journal of the Solar Energy Society; Smithsonian Radiation Biology Laboratories, 1244 Parklawn Drive, Rockville, Maryland 20853.

"Solar Energy Digest", P.O. Box 17776, San Diego, California 92117.

"Solar Energy Intelligence Report", P.O. Box 1067, Silver Spring, Maryland 20910.

Periodicals (cont.)

"Solar Age", SolarVision, Inc., Route 515, Box 288, Vernon, New Jersey 07462

"Solar Engineering", Solar Engineers Publishing Inc., Suite 880, 8435 N. Stemmons Freeway, Dallas, Texas 75247.

Selected Articles in Periodicals, listed chronclogically

"Orientation of buildings" Royal Institute of British Architects Journal, s3v39:777-99, September 1932.

"Solar house for a sunny hilltop" (J.L. Bennett House, Barrington, Illinois, G.F. Keck, Architect). Architectural Record 95:58-65.

"Solar heat gain through windows" (N.S. Billington) R.I.B.A. Journal s3v54: 177-80, January 1947.

"The solar house: analysis and research in test houses at Purdue", (F.W. Hutchinson) Progressive Architecture 28:90-5, May 1947.

"Test house heated only by solar heat" (Telkes' salt-storage system at Dover, Massachusetts) Architectural Record 105:136-7, March 1949.

"M.I.T. builds solar heated house" (first occupied test house at MIT) Architectural Record 105:135-8, April 1949.

"Design Procedure for a solar house", (G.S. Sharon, for New York region) Progressive Architecture 33:88-93, March 1952.

"Theory of sol-air orientation, a new approach to the problem of siting a building" (A. Olgyay and V. Olgyay) Architectural Forum 100:133-137 March 1954.

"Principles of solar house design" (A. Whillier, a particularly informative article) Progressive Architecture 36:122-6, May 1955.

"Solar space heating for houses" (A report on Association for Applied Solar Energy Symposium in Phoenix, and Tucson) Architectural Record 118:227-30, November 1955.

"Heating by sun power: world's first solar heated office building" (Bridgers and Paxton engineering office in Albuquerque, New Mexico) Progressive Architecture 38:153-5, March 1957.

"New England house brings solar heating a step closer" (M.I.T. Solar House IV described) House and Home 13:168-9, April 1958.

"Solar Energy: Today and Tomorrow" (J.I. Yellott, Exec. Director of Association for Applied Solar Energy (AFASE)) American Institute of Architects Journal 29:198-206, April 1958.

Selected Articles in Periodicals, listed chronologically (cont.)

"Solar house uses heat pumps for summer cooling, auxiliary heating" (AFASE prize-winning house in Phoenix) Architectural Record 123:222, June 1958.

"Solar heating for houses and three recently completed solar-heating installations" (Olgyay and Telkes discuss general information and the MIT IV, Löf and AFASE houses) Progressive Architecture 40:195-207, March 1959.

"Solar energy and building design" (Thomas Markus' Survey, to date) Architectural Review 135:456-464 and 136:68, June and July, 1964.

"How materials react to solar energy" (J.I. Yellott) Architectural Record 139:96-98, May 1966.

"Solar house heating" (Tybout and Löf, with costs for various regions) Natural Resources Journal, p. 268-326, April 10, 1970.

"Utilization de l'energie solaire" (work of Michel and Pillet) Arch. d' Aujourd'hui 167 p. 88-96, May 1973.

"The house that has its furnace in the sky" (Thomason's latest solar house) Popular Mechanics p. 150-154, June 1973.

"Solar energy in housing" (Colin Moorcraft's survey, to date) Architectural Design v. 43:634-643 and 652-661, November 1973.

"Can sunshine heat (and cool) your house?" (several solar houses discussed) Popular Science p. 78-81, March 1974.

"Can you use the sun to heat your pool?" (several collector techniques illustrated) p. 132-136, June 1974. Sunset (Northwest Edition)

"Using Solar Energy in Residential Housing" (Rittelmann; calculations and descriptions of solar heating and photovoltaic conversion systems for West Virginia house) The Construction Specifier, p. 20-30, July 1974.

"The varied and early solar energy applications of Northern New Mexico" (work of Van Dresser, Baer, etc.) AIA Journal, p. 37-42, August 1974.

"Energy Management is a Way of Life" (work of Frank Bridgers; large building applications of solar energy) Architectural Record 156:144-148, mid-August 1974.

"Sunpower" (Marguerite Villecco's wide ranging and detailed survey, to date) Architecture Plus, 84-99, September/October 1974.

"High Oil Costs Heat Up U.S. Solar Energy Research" (describes many solar applications to date), Engineering News Record, p. 32-42, Nov. 14, 1974.

"Solar Building in the Pyrenees" (with photos, diagrams or Trombe's storage-wall approaches) Architectural Design Vol. 45:13-17, January 1975.

Selected Articles in Periodicals, listed chronologically (cont.)

"How to Trap Solar Heat with Your Windows" (simplified calculations for solar gain through glass) Popular Science, p. 108-116, Feb. 1975.

"Now You Can Buy Solar Heating Equipment for Your Home" (comparisons of materials and heat transfer media; costs; list of current manufacturers) Popular Science, p. 75-77, 136-142, March 1975.

"New Concepts for Residential Use of Solar Energy" (solar collection and house form; AIA Research Corp. results) AIA Journal, March 1975, p. 21-28 and June 1975, p. 24-31, 41.

"Directory of Alternative Technology; Shelter, Energy", Architectural Design, Vol. 45, p. 232-242, April 1975.

"Solar Heating and Cooling" (Duffie and Beckman's summary) Science, 16 January 1976, Vol. 191, #4223, p. 143-149.

"The Autonomous Houses" (Peter Harper's extensive survey), "Generic Solar Houses" (Ian Hogan's analysis), and "Index of Alternative Technology" (5 year guide to AD articles on same), all from Architectural Design, January 1976, p. 19-52, 62-63.

"Active Type Solar Heating Systems for Houses: A Technology in Ferment" (William A. Shurcliff's informed analysis and observations), Bulletin of the Atomic Scientists, February 1976, p. 30-40.

OTHER SOLAR PUBLICATIONS FROM
THE CENTER FOR ENVIRONMENTAL RESEARCH:

Baker, M. S. and Reynolds, J. S.

CER 117 $1.00

"Insolation on Tilted Surfaces for Pacific Northwest Locations". Monthly average daily totals in Btu for 7 tilt angles, for 22 locations, Oregon through Alaska. 54 p., 1975.

Gray, R. L. and Baker, M. S.

CER 114 $2.50

"Survey of Solar Buildings". Consistent information format for 50 selected solar buildings in U.S.A. and other countries, with illustrations. 105 p., 1975.

Reynolds, J. S.; Larson, M. B. and Baker, M. S.

CER 116 $1.00

"The Atypical Mathew Solar House at Coos Bay, Oregon". Analyzes this house's performance for 1974-75 heating season. Presented at I.S.E.S. 1975 Conference. 29 p., 1975.

Students of J.S. Reynolds

CER 118 $3.25

"Energy Conservation and Solar Retrofitting for Existing Buildings in Oregon: an Architecture Design Class Project". Illustrated general information and studies for seven existing residences in Eugene area. 122 p., bound, 1975.

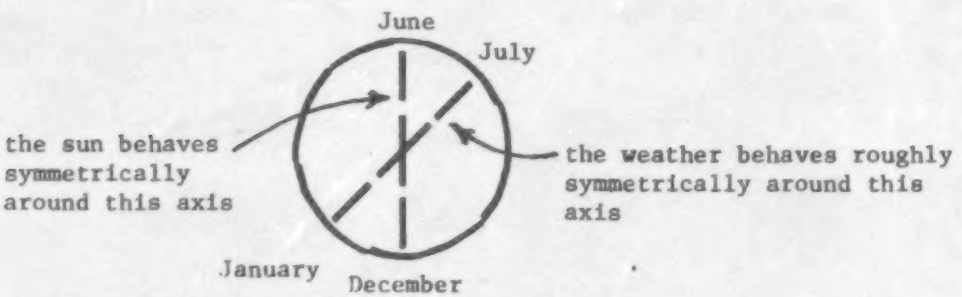
These prices include postage.

PART THREE: OTHER INFLUENCES ON REGIONAL ARCHITECTURE

The solar collectors previously discussed allow a part of the sun's energy to be stored each day, to be later utilized in the building. Other solar control devices will welcome sun at some times, filter or exclude it at others. Collectors and control devices could become an important characteristic of the Pacific Northwest regional architecture, as have influences such as wind and rain.

About a generation ago, fixed external sun control devices were widely installed, lending an airy three-dimensionality to the facades of that era. Two shortcomings of such fixed controls are:

- they deprive the occupant of deciding upon his momentary relationship with the sun.
- they either exclude the sun too early in the spring, or admit it too early in the fall.



Some alternatives to the fixed external sun control are presented here.

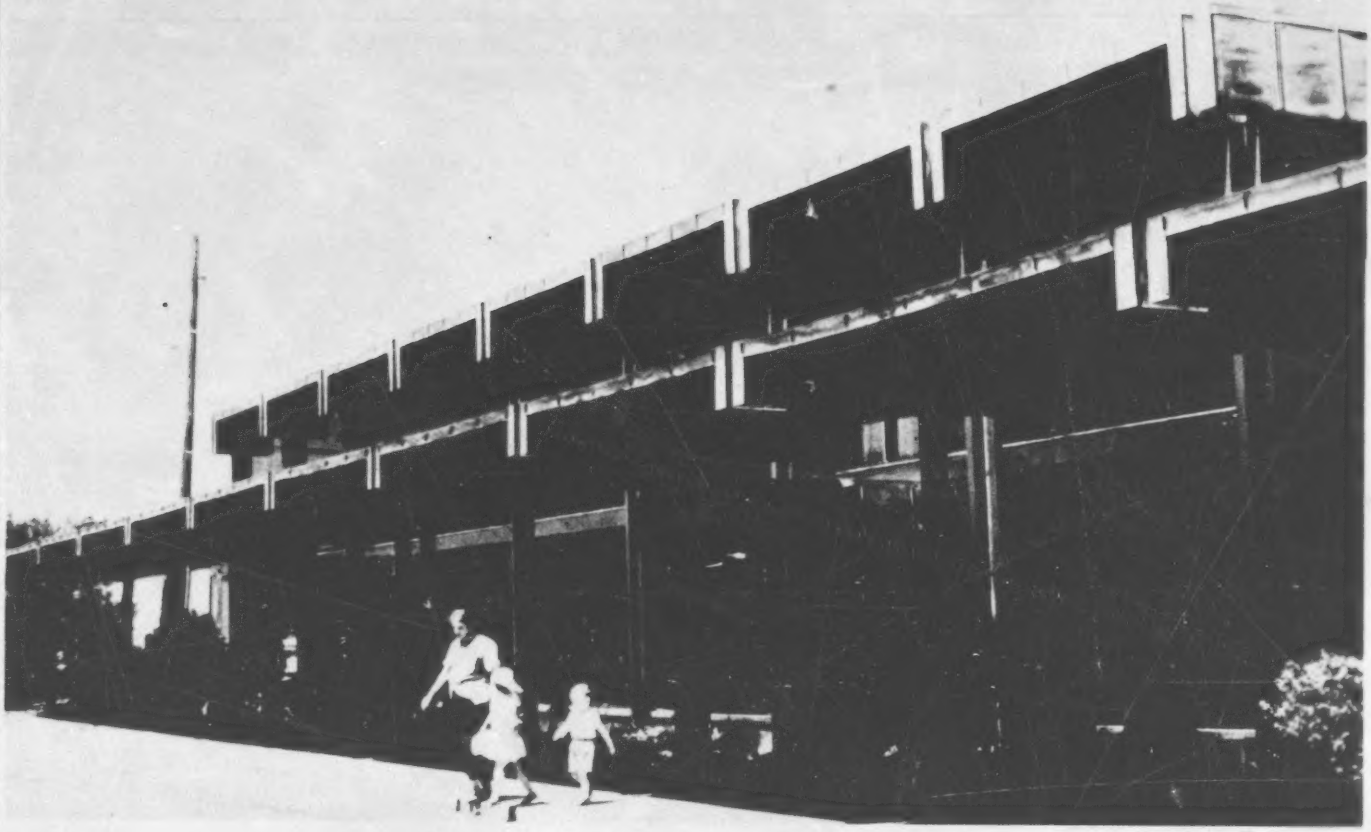
Finally, to underline the influences of local climate on regional designing, several graphic presentations are included for the Eugene area. Their meaning and possible usage are explored.

Summer Solstice
11:30 A.M.
Av. Outdoor Temp. 67°

Winter Solstice
11:30 A.M.
Av. Outdoor Temp. 39°

SUN AS ENEMY?

This branch bank faces south, full solar exposure guaranteed over its own parking lot. Partial seasonal protection is afforded by the main roof's overhang; less clear is the solar control provided by the covered walkway. (Oregon's winter rain makes its function more obvious.) The winter sun, bathing the facade in one photograph, is made as unwelcome as the summer sun by the fashionable "solar heat rejecting glass"; a harmonious brown in color, but forever oblivious to the sun's yearly change from enemy to friend.

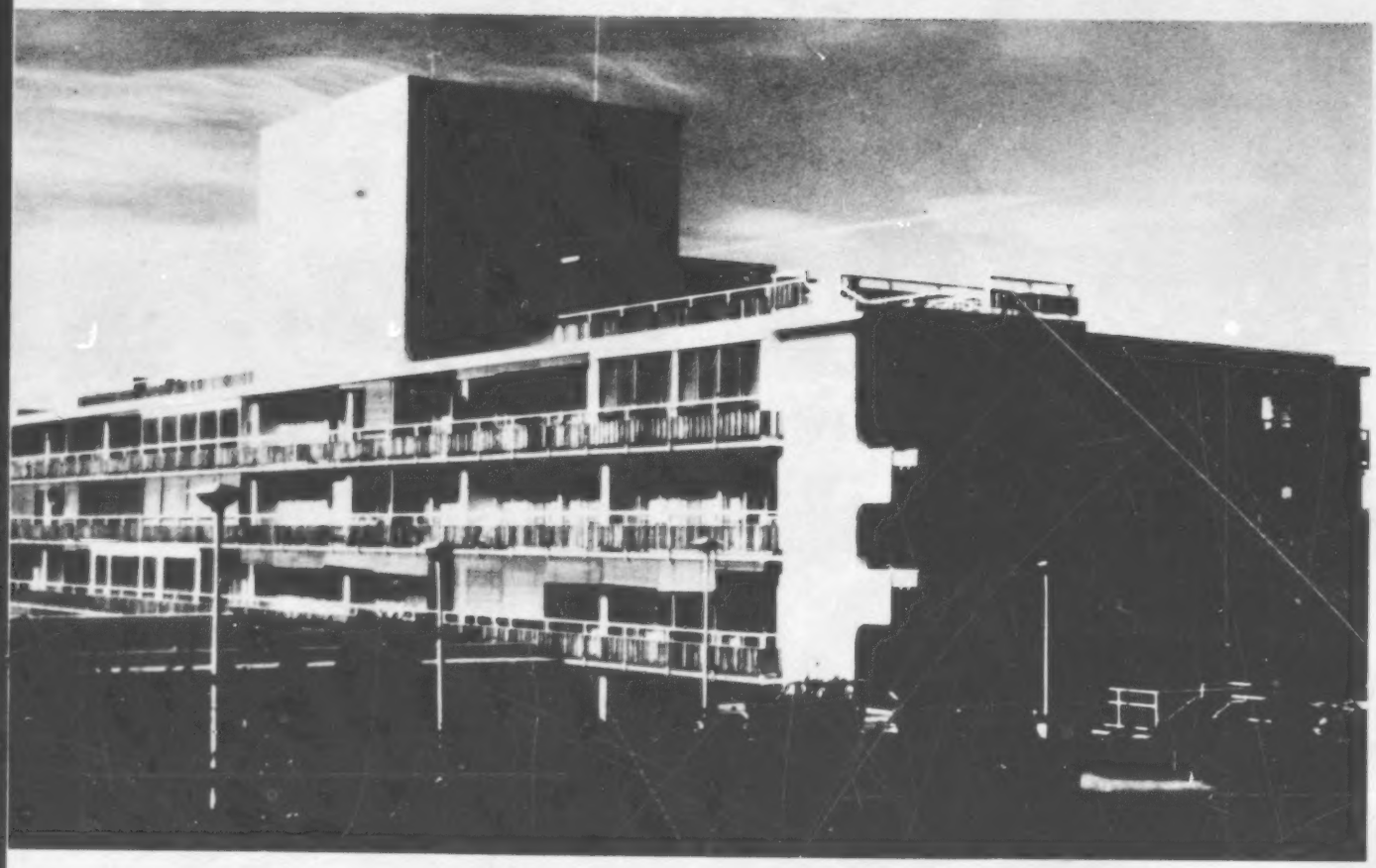


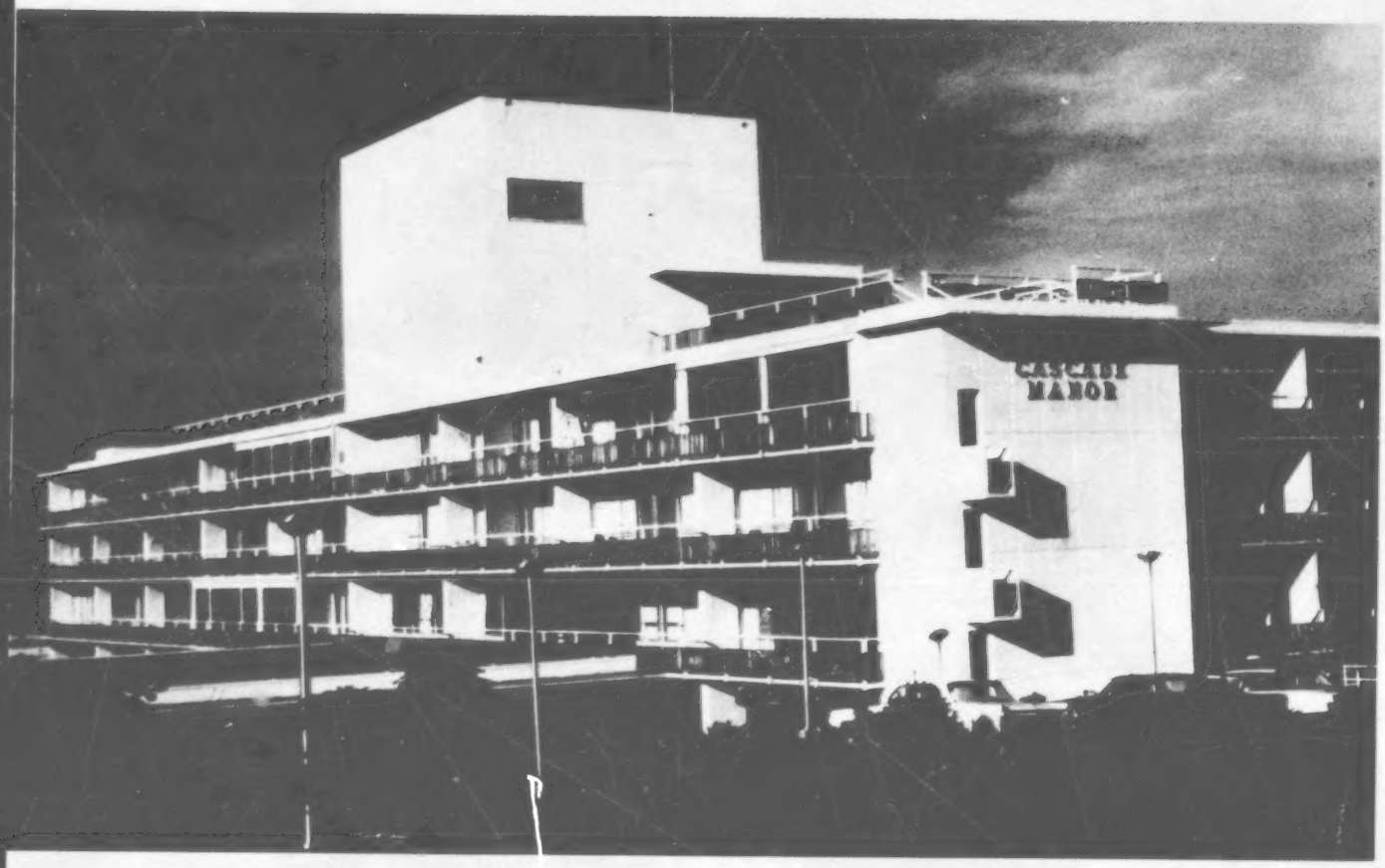
Summer Solstice
4:15 P.M.
Av. Outdoor Temp. 70°

Spring Equinox
4:15 P.M.
Av. Outdoor Temp. 53°

PEOPLE AND SUN

These west facing private balconies serve the residents of a retirement home. While some fixed solar control is provided by the ceiling and walls of the balconies, it is the adjustable sun-screens that allow each occupant to choose the extent of solar penetration at any moment. The sun-screens also enliven the facade. While most residents welcome full sun at the spring equinox, a few seem bothered by the glare and are using their sun-screens as filters.




CASCADE
MANOR

Fall Equinox
4:45 P.M.

Spring Equinox
4:45 P.M.

TREES AND SUN

This south-facing row of shops is provided with a self-adjusting solar control device: a deciduous tree. The photographs show the identical solar patterns found on Sept. 21 and Mar. 21, yet the average temperatures in Eugene for these alike solar days are quite unalike:

	8:30 A.M.	11:30 A.M.	4:45 P.M.
Sept. 21	55	67	75
Mar. 21	43	51	53

Deciduous trees also influence daylight distribution, provide a window "louvre" which most people find pleasant to look through, and provide a rustle of leaves in a summer breeze that reinforces a feeling of being cooled. Seasonal changes in visual structure, color, texture, aroma, and sound all are possible.

Winter

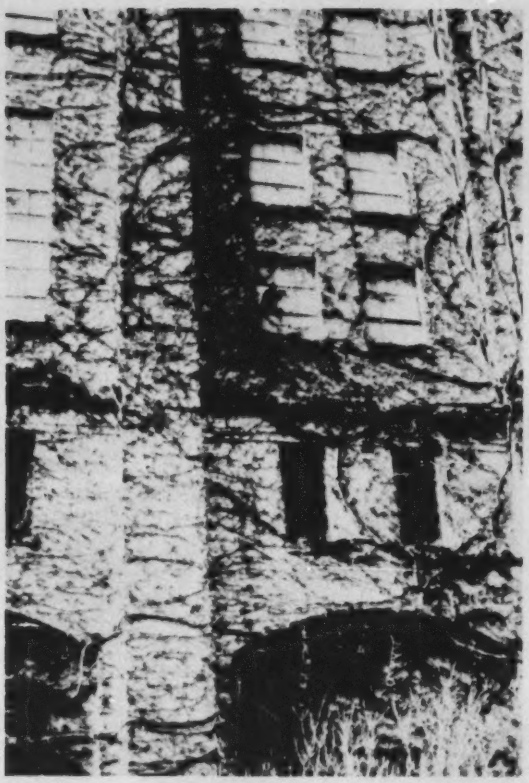
Spring

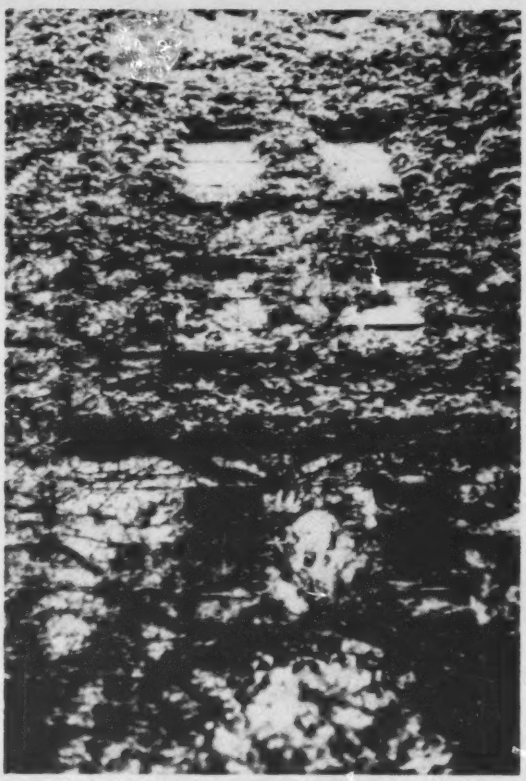
Summer

VINES AND SUN

Another solar control device that responds both to sun and temperature is the deciduous vine. Here, a grapevine covers an old barn near Eugene. (It was planted to hold down the new tin roof, which couldn't be nailed down to the old wooden shingles because of advanced decay.) An unusually cold spring would delay the unfolding of the bright green leaves; an early freeze turnes the deep green mature leaves to bright yellow, and further cold and wind remove them. A vine can cover a roof, an especially valuable characteristic in summer; and autumn brings in this case, ripe grapes.

On the next page, the wall of the basketball court at the University of Oregon is covered with Virginia Creeper. Its berries feed birds, not humans; its fall color is that famous deep scarlet.

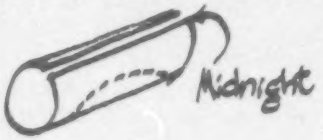




EUGENE CLIMATOLOGICAL DATA "TIMETABLES"

Not maps but timetables, these charts could be presented as continuous cylinders on both axes:

The Yearly Cycle



The Daily Cycle

Source is the local climatological data for Mahlon Sweet Field (Eugene Airport), U.S. Dept. Commerce, Environmental Science Services Administration. The data, available at 3 hour intervals, was averaged for the 1st, 11th and 21st of each month, period July 1, 1964 through March 21, 1972 (yielding 8 year average for most readings). This data then was fed into separate computer plots for dry bulb temperature, relative humidity, sky cover, wind speed, and wind direction. Those presented here combine temperature with humidity, and wind speed with direction.

These studies are for the purpose of exploring low-energy building design in general, and not particularly solar energy utilization, although they provide some insight into potentials for solar energy applications.

The weather bureau's airport location may be influenced by local microclimates as follows: proximity to a large shallow water body (Fern Ridge Reservoir); surrounded by agricultural lands with some irrigation and prevalent summer grass field burning; wind patterns unobstructed by any abrupt nearby topographic changes; station downwind from Eugene's urban area only about 1/5 of the year.

TEMPERATURE & RELATIVE HUMIDITY

The consistent inverse relationship between dry bulb temperature and relative humidity can be seen here; the lowest average RH of 35% occurs during the highest average temperatures $>80^{\circ}$, on July mid-afternoons. The highest RH $>95\%$ occur during some of the lowest temperatures 40°-50°, on October-November nights before sunrise.

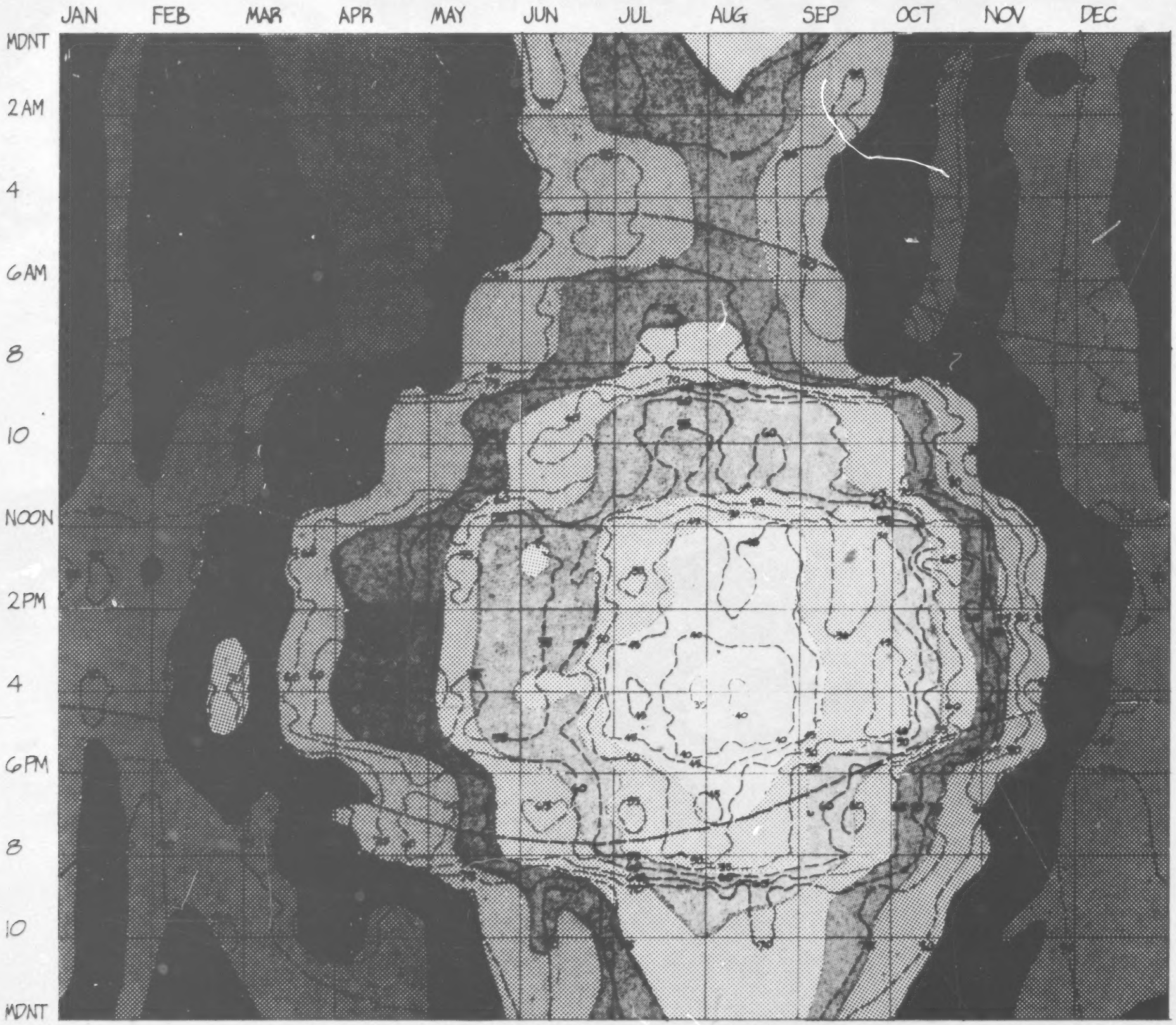
The "traditional warm week" which brightens our late January or early February winter seems to show up on the temperature, but not on the humidity, table.

The pronounced cloudy weather of June compared to May is not accompanied by a decrease in temperature, and only slightly by a noon to 4 pm increase in relative humidity.

As on the Sky Cover Chart, the advent of warmer, less humid spring weather occurs much more gradually than the sudden return to winter conditions compressed into October and November.

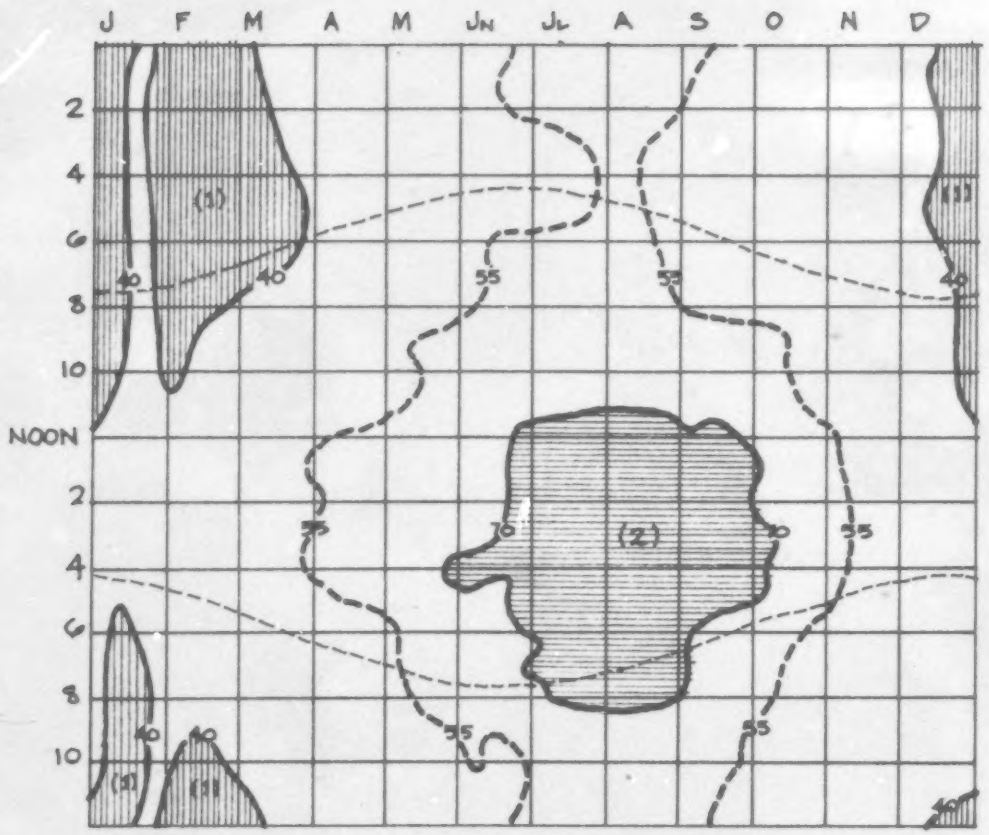
High lighting levels in commercial buildings, fashionably left on all night, often result in such structures "balancing" (requiring cooling) in the 40°-50° outdoor range or even lower. Assuming balance at 45°, such cooling appears to be required here 70% of the year.

Maximum averages:	83°; 97% RH
Minimum averages:	35°; 33% RH



TEMPERATURE & HUMIDITY

EUGENE



COOLING WITH OUTDOOR AIR, OR STORING EXCESS HEAT:

Assume here that the high lighting levels have produced a building which "balances" at 40°F outdoor temperature. With lights never off, this time-table shows the small (shaded) portions of the year during which 1) supplementary heat is needed or 2) mechanical cooling does all the cooling work (above 70°F).

For the greater part of the year, cooling can be accomplished by introducing cool outdoor air to the interior spaces. (The dotted line occurs at 55°F; below this point, no mechanical cooling should be required; above this point, mechanical cooling becomes increasingly necessary to help with the cooling work.)

If lights are turned off at night, the portion of the year between 40° and 70° represents possible storage of the excess lighting heat. This is removed from the spaces by day and stored for nighttime supplementary heat which now becomes necessary.

Note that a heat storage tank is a step toward solar supplementary heating, also.

SKY COVER

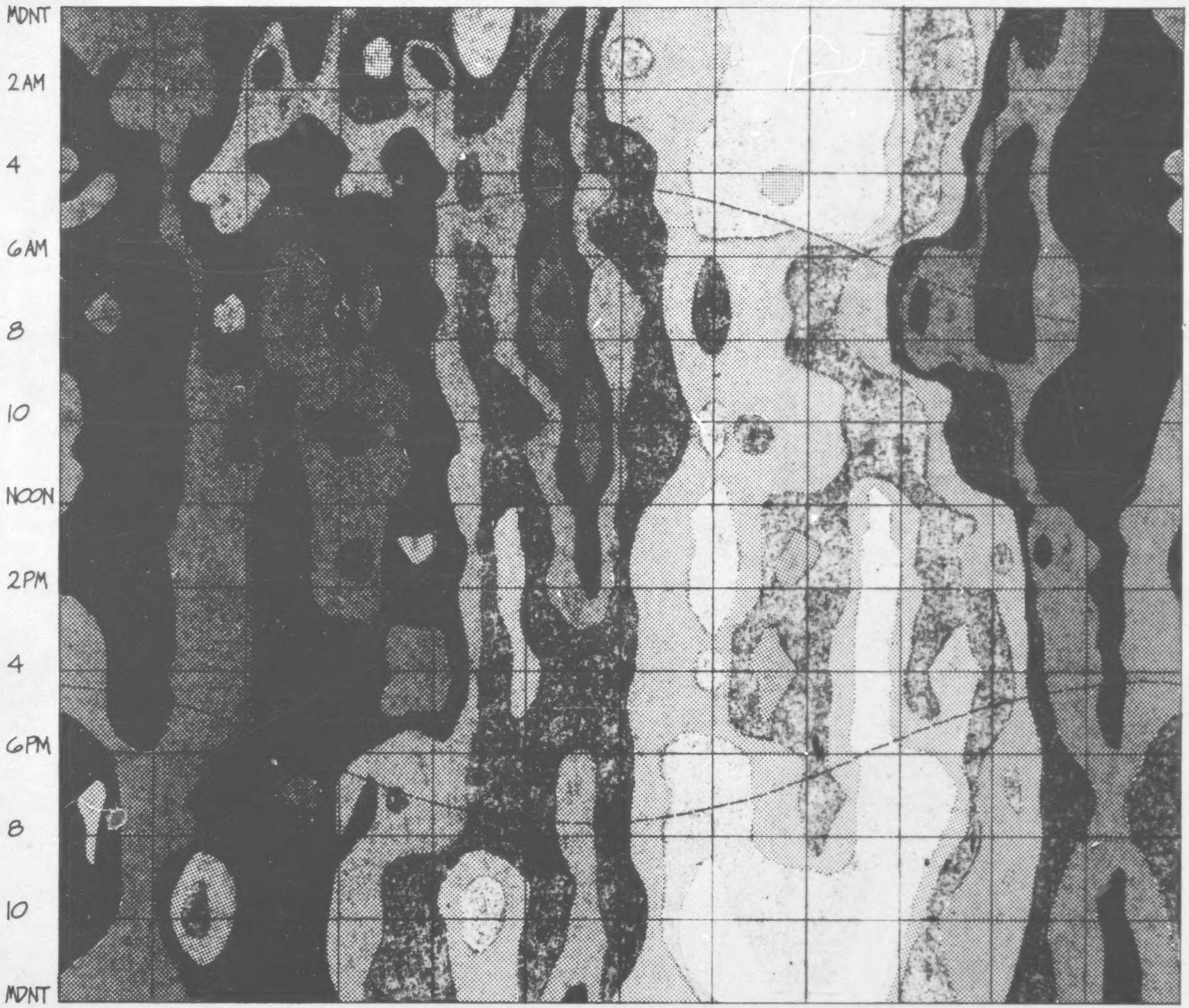
The clearer skies of summer are shown, although 40 to 60% average cover during daylight hours seems at odds with experience. This is due to the frequent condition of such clouds being so high and often so thin that their impact on incoming radiation is unnoticed. This is indicated in the climatological data as "unlimited ceiling" or "cirriform cloud ceiling of unknown height"; but it averages out here as up to 60% cover.

A sharply increased percentage of sky cover is noticeable in June compared with May; this doesn't seem to influence temperature or humidity, but does correspond to increased velocity and frequent directional changes of wind in June as compared to May. April is also more cloudy than March, but March wind speeds are somewhat greater than April's.

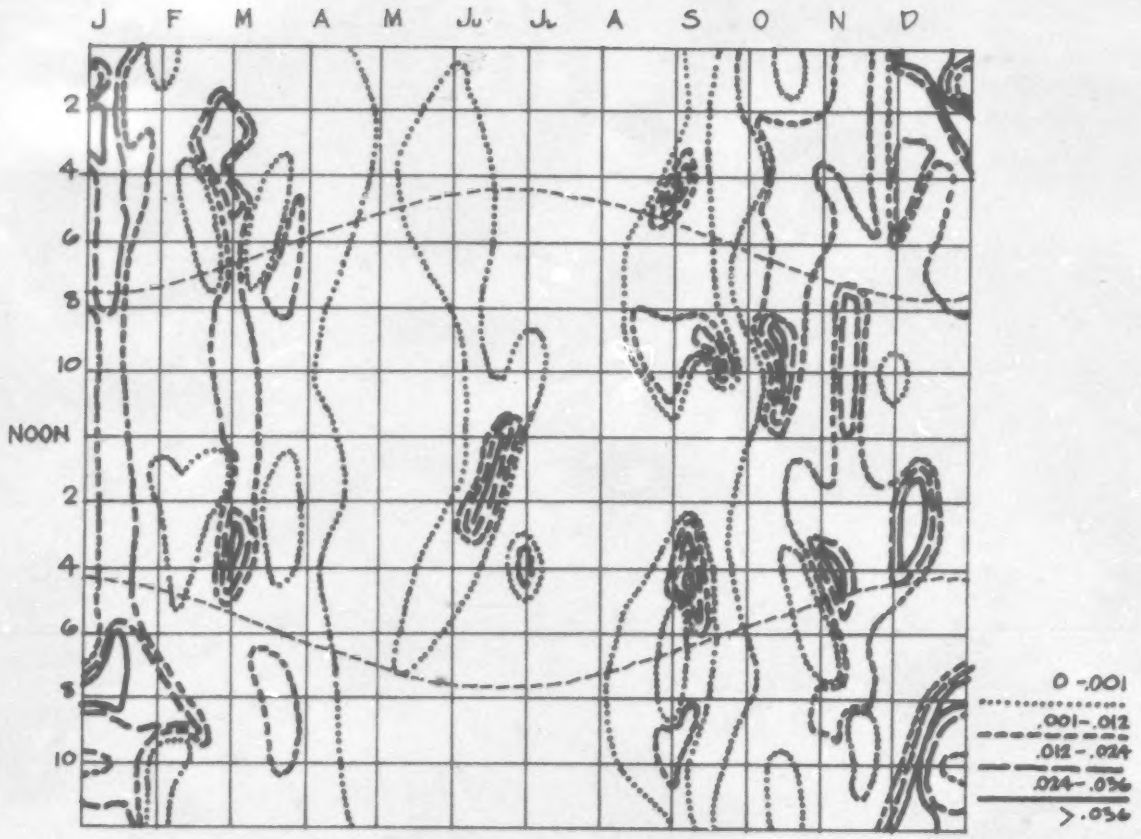
The clearest skies are summer nights; this could be due in part to grass field open burning by day, prohibited after dark, during the July to early September periods.

A very rapid increase in % sky cover occurs in October and November compared to spring's gradually thinning cover.

Maximum average:	100%
Minimum average:	10%



SKY COVER **EUGENE**



PRECIPITATION TIMETABLE:

Showing average hourly rainfall in hundredths of inches, this illustrates the rather slow steady rain of the Pacific Northwest. While some correspondence with sky cover is certainly expected, some surprisingly heavy momentary precipitation occurs in September, October and November. This corresponds to "storm season." By contrast, rather cloudy February has some large dry spots. As expected from cloud cover timetable, May is drier than June.

Maximum average hourly rainfall: .089 inch.

WIND

Directionality is superimposed on time here, giving maplike qualities to this particular timetable.

Direction	% of year, approximate
NNE	0
ENE	1%
ESE	7%
SSE	18%
SSW	29%
WSW	17%
WNW	23%
NNW	6%

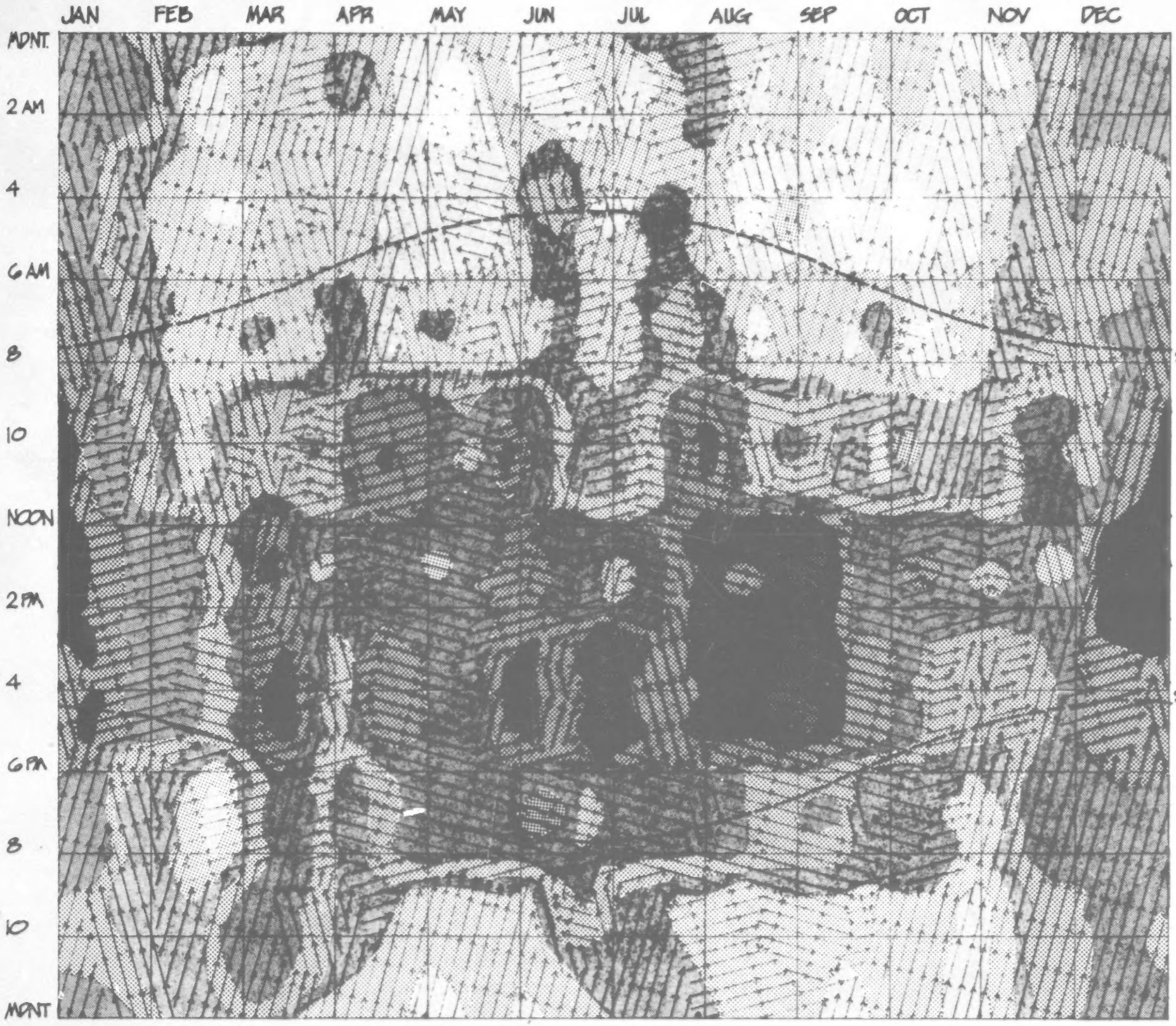
Perhaps the clearest feature of this "map" is the higher wind speed, year-round, during daylight hours. Also evident are the highest velocities during the afternoons in Dec-January, June, July, August and September.

The least windy month in daytime is February followed by November; both these months have the steadiest daily wind speeds, in the 3-8 mph range. Most extreme daily speeds occur in September, less than 3 mph at dawn, over 10 mph just after noon.

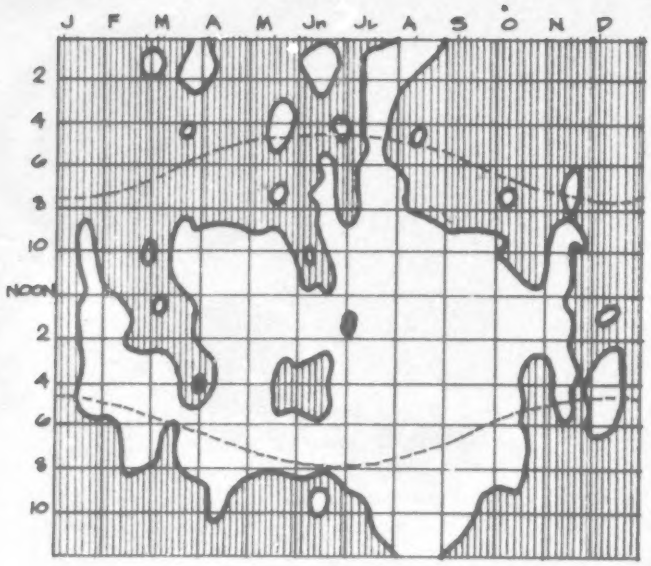
The high velocity and northwesterly direction of the winds during the highest temperatures indicate that wind ventilation of buildings deserves more attention in Eugene. (Air pollution and noise, of course, often rule out this possibility.) The high velocity and southerly winds during the two coldest months indicate that protective design is warranted.

Wind from the northeast only occurs in these averages around 4 pm, late March-early April. The clear summer night skies are accompanied by lower velocity winds and RH generally above 70%; radiant sky cooling without excessive evaporative water loss seems possible.

Maximum average velocity:	13 mph
Minimum average velocity:	2 mph


JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
MDNT.
2 AM
4
6 AM
8
10
NOON
2 PM
4
6 PM
8
10
MDNT
SUNRISE
SUNSET
WIND MOVING NORTH
MPH:
<3
3-4
4-5
5-6
6-7
7-8
8-9
9-10
>10

WIND EUGENE

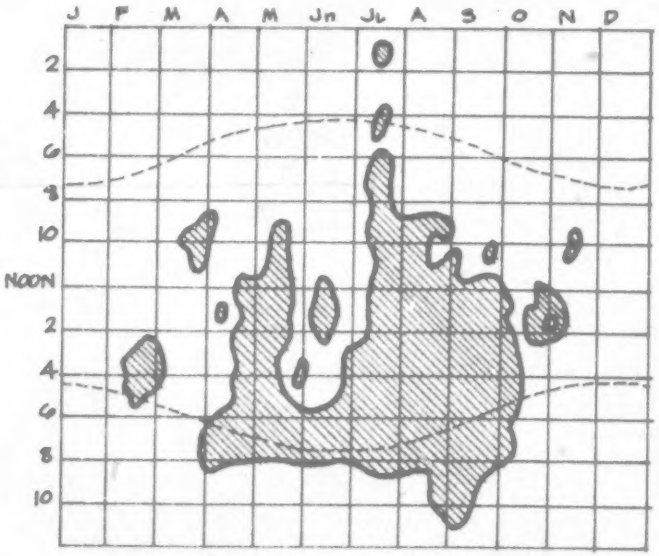


RAIN-BEARING WINDS:

Much of Eugene's precipitation occurs with winds from south-southeast through south-southwest. The timetable for those winds is shown above. Most of November, December, January and February's average wind direction is represented here.

COOLING BREEZES:

The warmest portion of the year corresponds with winds from west-northwest through north-northwest. The timetable for those winds is shown below. Most of July, August and September afternoon's average wind direction is represented here.



SUGGESTED FURTHER RESEARCH

Of the many needs for more investigation that are evident in this paper, these few seem particularly apparent:

1. Comparing total daily electrical consumption with the total contribution of daily solar radiation on some assumed total number of square feet of solar collectors, for each heating season. This gives needed depth to the Langley-degree day-peak megawatt studies, and allows utilities to consider investment in customer's solar collectors as compared to generating facilities in the immediate future.

2. Measurement of Langley's daily at a wider network of stations, year round, both on horizontal and on tilted surfaces.

3. Eugene Climatological Data timetables for footcandles of daylight (data unavailable), and for Langleys solar radiation (data incomplete).

4. Overlay sheets for the Eugene timetables, showing various traditional and possible hours/seasons of operation for various building functions, to minimize energy expended by such functions.

5. Overlay sheets for Eugene timetables, showing heat generated internally by various combinations of lighting, occupancy levels, etc., to see where heating and cooling seasons occur for buildings.

6. A search for and publication of locations and sizes of solar energy utilizations in Northwest buildings. Selected examples should then have their performance measured throughout at least one heating season.

7. Timetable presentations of climatological data for other areas in the Pacific Northwest.

ABOUT THE AUTHOR

John S. Reynolds has taught at the University of Oregon since 1967. He was also elected to the Eugene Water and Electric Board in 1972 and was a member of the '73-'74 Governor's Energy Advisory Committee.

He received a Bachelor of Architecture degree in 1962 from the University of Illinois (Urbana) and a Master in Architecture degree from M.I.T. in 1967. He spent 1963-64 in Italy on a Fulbright Scholarship and has worked in architectural offices in Illinois, Arizona, Massachusetts and Oregon. He is a registered architect in the latter two states.

The living-working experiences in these climates and cultures has reinforced his belief in the appropriateness of regional architecture, and he remains optimistic about solar energy utilization in the Northwest despite his memories of the sunny Arizona desert.

The author, his wife and three children live in a 1925 house near the Oregon campus.

END